ASTRONOMY®

July 1992 **U.S. $2.95**
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Absolutely uncompromised, textbook-perfect image quality combined with revolutionary German-type equatorial mountings and optional computer drives.

Meade complete ED Apochromatic Refractors include optical tube assembly with giant 2.7″ rack-and-pinion focuser, equatorial mount, field tripod, 8 x 50mm viewfinder, giant 2″ diagonal mirror, and Super Plössl 26mm eyepiece:

4″ f/9 Model 102ED, complete	**$1795.**
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7″ f/9 Model 178ED, complete	**4995.**
#1664 Electronic Drive System	**295.**
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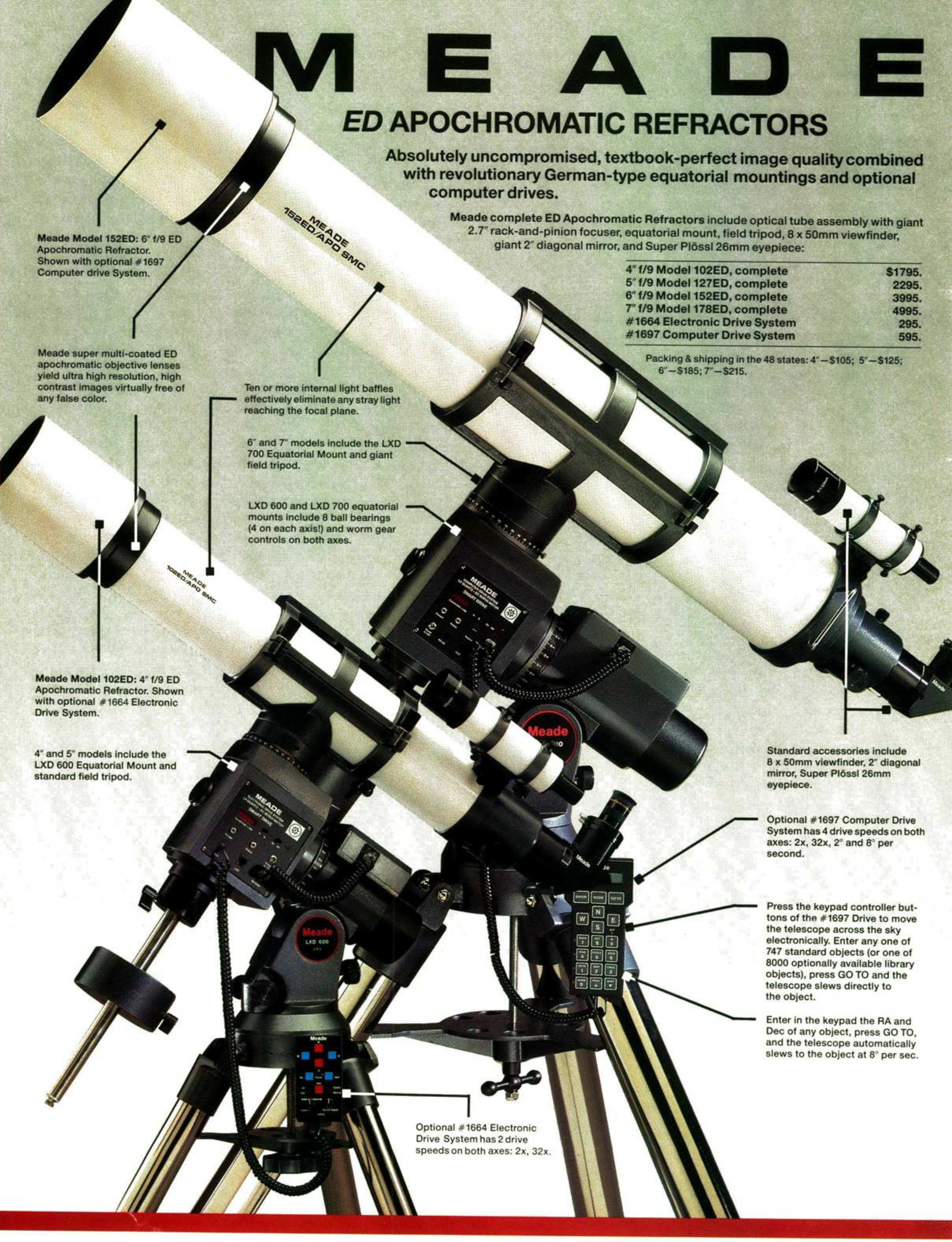

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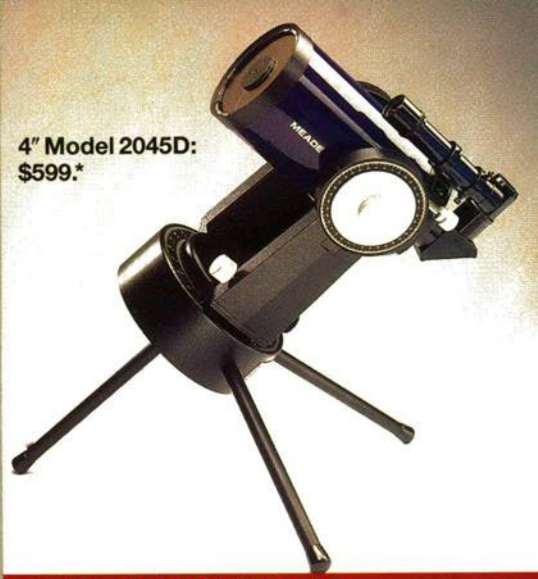
Optional #1697 Computer Drive System has 4 drive speeds on both axes: 2x, 32x, 2° and 8° per second.

Press the keypad controller buttons of the #1697 Drive to move the telescope across the sky electronically. Enter any one of 747 standard objects (or one of 8000 optionally available library objects), press GO TO and the telescope slews directly to the object.

Enter in the keypad the RA and Dec of any object, press GO TO, and the telescope automatically slews to the object at 8° per sec.

Optional #1664 Electronic Drive System has 2 drive speeds on both axes: 2x, 32x.

10″ Model 2120A:
$1379.*
8″ Model 2080A:
$1099.*



Meade Standard Series 8″ and 10″ SCT's: advanced technology at economical pricing levels.

No other comparably-priced Schmidt-Cassegrains offer the optical and mechanical features of the Meade Standard Series:

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- **Standard-Equipment Motor Drive System:** Not an add-on, but *a built-in 5.75″ worm gear drive that is the most accurate available on any SCT in this price range.*
- **Variable-Height All-Metal Field Tripods:** The finest tripods yet developed for SC telescopes, the ultimate in rigidity and low-damping time.
- **Optional Systems:** Unlike competing German-mounted SCT's with small worm gears, Meade Standard Series SCT's permit almost unlimited growth potential—use the **#46 Dual-Axis Drive Corrector** for deep-space photography with the **Off-Axis Guider** system; **#929 2″ Diagonal** with **2″ Super Wide Angle** eyepieces for breathtaking wide-field observing; and much more. ***See the Meade catalog for details!***

4″ Model 2045D: the Ultraportable Meade SCT

For the beginning astronomer the lightweight and easy-to-use Meade 2045D packs a powerful potential for serious observing. As a second telescope for the advanced amateur, the 2045D permits wide-ranging observations in locations inaccessible or inconvenient to larger instruments. Each telescope includes optics manufactured to the same high performance standards as larger Meade models. The DC drive system operates from a micro battery pack for convenient field use. Full accessorization is available for virtually any field application.

Specifications: Model 2045D—Complete with 4″ f/10 Schmidt-Cassegrain tube assembly with super multi-coated optics; fork mount with setting circles, manual slow-motion controls, and locks on both axes; 12-volt DC pulse motor, spur gear drive system; AA battery pack (batteries are not included); tabletop tripod system; eyepiece holder/diagonal prism; coated MA 25mm (40X) eyepiece (1.25″); 5 x 24mm viewfinder. . . . . **$599.**

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Specifications: 8″ Model 2080A—Complete with 8″ f/10 Schmidt-Cassegrain optical tube assembly; fork mount with setting circles, manual slow-motion controls and locks on both axes; 5.75″ worm gear motor drive system (115v./60Hz); eyepiece-holder (1.25″); diagonal prism; coated MA 25mm eyepiece (1.25″); 6 x 30mm viewfinder; equatorial wedge; variable-height all-metal field tripod. . . . . **$1099.**

Model 2080B—Identical to Model 2080A, but in addition with Super Multi-Coated optics. . . . . **$1149.**

Packing & shipping on either 8″ model in the 48 states: . **$95.**

Specifications: 10″ Model 2120A—Complete with 10″ f/10 Schmidt-Cassegrain optical tube assembly; fork mount with setting circles, manual slow-motion controls, and locks on both axes; 5.75″ worm gear motor drive system (115v/60Hz); eyepiece holder (1.25″); diagonal prism; coated MA 25mm eyepiece (1.25″); 8 x 50mm viewfinder; equatorial wedge; variable-height all-metal field tripod. . . . . **$1379.**

Model 2120B—Identical to Model 2120A, but in addition with Super Multi-Coated optics. . . . . **$1449.**

Packing & shipping on either 10″ model in the 48 states: **$125.**

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☐ **For further information on Meade ED Apochromatic or Schmidt-Cassegrain telescopes, visit one of the hundreds of Meade dealer showroom locations throughout the USA; or contact one of the authorized mail-order dealers at left. Or call Meade Instruments toll-free at 1-800-854-7485 (in California 714-556-2291).**

☐ *All prices shown are suggested USA mail-order retail prices, exclusive of sales taxes or credit card charges, if applicable.

☐ The all-new **1992 Meade General Catalog**—$3.00 postpaid—is available from any authorized Meade dealer or directly from Meade Instruments.

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ON THE COVER: New stars are born from the recycled dust of old, enriching each new stellar generation with heavier elements. Astronomers probe the history of the Galaxy by analyzing what stars are made of. To learn more, turn to page 28. Photo of Rho Ophiuchi complex ©Anglo-Australian Telescope Board.

BRISTLING WITH EXPERIMENTS, the shuttle Atlantis flew in March on a mission to explore the Earth, Sun, and stars. One of those instruments was a telescope that took wide-angle images of the ultraviolet sky. For a first report on this special science mission, see page 26.

NASA

ASTRONOMY®

July 1992

Vol. 20, No. 7

28 Galactic Archaeology

The Milky Way's ancient history lies buried in its stardust. By Ken Croswell.

36 Desperately Seeking Jupiters

Planets around Sun-like stars may be less common than astronomers thought. By David Bruning.

42 Ulysses Meets a Giant

In February, Ulysses became the first spacecraft to visit Jupiter in over 12 years. By Alan Dyer.

44 A New Slant on Earth

If Earth rotated on its side, our climate would be turned upside down. By Neil F. Comins.

50 ASTRONOMY Sky Almanac

60 How to Improve Your Image

Get sharper views by learning where and how to set up your telescope. By Rod Pommier.

66 Exploring the Wonders of Scutum

A small patch of the summer Milky Way contains a big selection of deep-sky delights. By Robert Garfinkle.

75 Summer's Gift to Comet Observers

Follow a comet named Shoemaker-Levy as it glides through the stars of Ursa Major. By Richard Talcott.

80 Going Digital in Color

Capture state-of-the-art images in color with a CCD camera. By Richard Berry.

Departments

6 **Behind the Scenes**
6 **Letters**
13 **Viewpoints**
Observing Companion
18 **AstroNews**
A Black Hole for M32
24 **Amateur News**
Star Parties in Kansas and Texas
26 **Space News**
Atlas: Mission to the Earth, Sun, and Stars
87 **Reader Reports**
Good Geminids!
94 **Astronomy Books**
100 **AstroBytes**
New Software Roundup
104 **New Astronomy Products**
108 **Meetings and Events**
112 **Readings and Resources**
112 **Credits**
114 **Advertiser Index**

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The Audit Bureau

Behind the Scenes

ARCHAEOLOGY OF A GALAXY?

It may strike you as strange to link a terrestrial subject like archaeology with the Milky Way, but the fact is some astronomers *are* digging up the Galaxy's ancient history. Of course, any of us can see back in time a short way simply by looking up at the sky. Vega, for example, looks tonight as it really was back in 1967 because that's how long its light has taken to reach us.

But this technique won't work with the Milky Way — even its most distant parts lie much too close for astronomers to see back very far. To uncover the truly ancient history of the Galaxy, astronomers must dig with a different kind of tool: a spectrograph that can reveal the chemistry of the Galaxy's stars and the dusty gas that gave birth to them. July's feature story (page 28) will let you look over the shoulders of astronomers as they probe eons into the Milky Way's past — to a time when the Galaxy as we know it, and indeed our own planet, couldn't have existed.

Another kind of astronomical digging has *not* produced results and that has a few astronomers worried. Theories of star formation predict that lots of tiny not-quite-stars and a great many super-Jupiter-type planets should exist. Yet increasingly sensitive surveys have not revealed any. For an up-to-the-minute look at this developing puzzle, see page 36.

If you own a telescope, two treats lie in store this month. First, the star clouds of Scutum, the Shield — gloriously rich in stellar clusters — return to view in the evening sky (page 66). Scutum provides some of the Milky Way's grandest sights in any instrument. Second, a new telescopic comet will make a bold sweep up past Polaris and down into Ursa Major (page 75). Don't miss it.

The hottest topic in astrophotography today is color imaging with a charge-coupled device, or CCD. In the February issue, Richard Berry told how CCD imaging relates to more traditional astro-picture-taking. On page 80 this month, he gives you the lowdown on how to take color pictures with astronomical CCDs. It's a lot easier than you'd think. What's more, it builds on an old technique that's been kicking around astrophotography for years and years. Where is all this headed? I don't know. But I for one can't wait to see what will happen as this technique begins to infiltrate astrophotography in a big way over the years to come.

Sincerely,

Robert Burnham
Editor

P.S. To officers of astronomy clubs: We publish *ASTRONOMY Network News*, a bimonthly newsletter that's full of information and ideas on how your club can grow in size and strength. For a free subscription, just drop a note on club stationery to Tammi Scherbarth here at the magazine.

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Letters

Help Needed for Astronomers in the Former Soviet Union

The American Astronomical Society (AAS) urgently requests donations to support astronomy and astronomers during the current economic crisis in the Commonwealth of Independent States (CIS), the former Soviet Union. The situation has deteriorated to the point where many good scientists, including an entire generation of young astronomers, face grave difficulties remaining in astronomy.

This is an opportunity for the professional and amateur astronomy communities to come together to advance astronomy by aiding astronomers in the CIS. The small salaries of these astronomers (between $50 and $100 per year) means that a moderate amount of money can help in a meaningful way, provided action is taken quickly. Funds raised here will be used to support a small grants program in the CIS. Grants of $100 to $200 will be made directly to a large number of CIS astronomers on the basis of current scientific productivity and the strength of their proposal for future research. Recipients will be nominated by a committee based in the CIS, but chosen by the AAS and headed by Professor Alex Boyarchuk, the current president of the International Astronomical Union.

Donations should be sent in the form of checks to the AAS Executive Office, 2000 Florida Avenue NW, Suite 300, Washington, DC 20009. Donations are tax deductible. — *John Bahcall, president, American Astronomical Society, Princeton, New Jersey*

Big Bang over Big Bang

I enjoyed Jeff Kanipe's article "Beyond the Big Bang" (April 1992). The plasma cosmologists are right to point out the inadequacies of gravity-based models of galaxy evolution. But they are probably going too far when they discount the Big Bang theory in the process.

The Big Bang theory describes the origin of the universe fairly well, and plasma cosmology describes galaxy formation fairly well. It seems that a merger of these ideas would be a perfect match for reality, perhaps with a dash of inflation. In his article Mr. Kanipe says that "a fundamentally uniform plasma will eventually break up into cellular structures that look similar to the large-scale structures seen today." The Big Bang provides just such a uniform plasma. — *Edward Keyes, Clinton, Tennessee*

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Patented Tele Vue eyepiece designs started a "space-walk" revolution. Bringing you far more field, sharpness and contrast than ever before. And still today, genuine Tele Vue Plössl, Wide Field, Panoptic and Nagler eyepieces deliver greater apparent field and edge sharpness than any other brand. All models have rubber eyeguards and each eyepiece is full field inspected before it leaves our hands for yours.

The more eyepieces you order, the more FREE items you receive. So, get your friends together and pool your orders for best selection. This offer ends September 30, 1992. Applies to merchandise in-stock at time of order. Take a Tele Vue out tonight and discover the eyepieces designed for a lifetime of viewing enjoyment.

"After seeing the recent ad with all the letters touting (competitive) eyepieces, I had to respond. I consider myself a very critical observer. Using a 10" f/5.6, I found the Tele Vue 40mm Wide Field superior to the (competitor) in sharpness, both center and edge. I have used very expensive and inexpensive eyepieces. I have found none optically superior to Tele Vue for astronomical purposes." - Kenneth Drake, Houston Astronomical Society

"Our observatory has a 16" f/5, and I recently tested my 26mm and 17mm Tele Vue against a new (5-element) competitive "Plössl". The Tele Vue eyepieces were much sharper, with more contrast. Sharpness at the edge of the field was far superior." - Steven Sherrod, TX

"Your eyepiece (20mm Nagler) has given me the most pleasant case of insomnia imaginable." - Tom Lorenzin, Author of 1000 + Guide to Deep Sky Observing

Tele Vue

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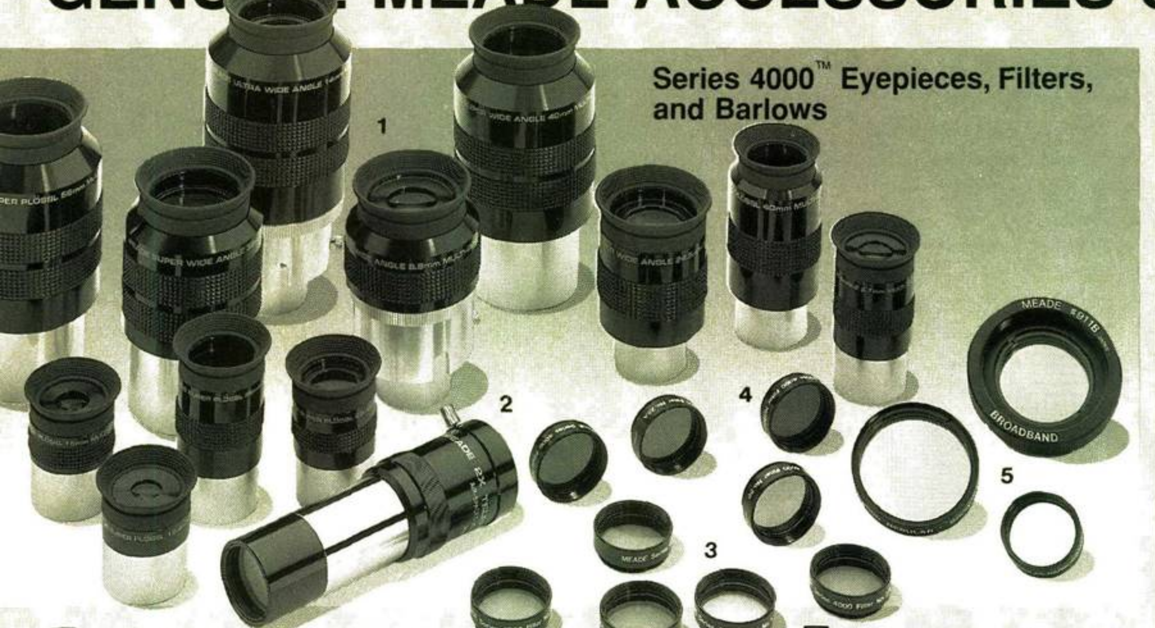

Series 4000™ Eyepieces, Filters, and Barlows

1 The World's finest telescope eyepieces now include rubber grips and soft rubber eyeguards for an even better observing experience! All eyeguards fold down for eyeglass wearers—a feature not available on competing brands. Best of all, **Meade Series 4000's are guaranteed to deliver more field, more contrast, and more image sharpness than any other brand at any price, or your money back.*** For splitting the closest doubles, revealing tenuous, faint nebulosity in deep-space, or studying hairline lunar and planetary detail, Meade multi-coated Series 4000's are the oculars that serious observers insist upon. ***"Clearly the best."***

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56mm (52°, 2") **219.95** (3.18)

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Ultra Wide Angles (8-elements, 1.25"; 84°):
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14mm(1.25"/2"): **249.95** (3.18)

*at participating dealers; see catalog for details.

2 **#140: Series 4000 2x Apochromatic Barlow Lens** (1.25")--The original Meade 3-element, air-spaced, multi-coated design. Absolutely unmatched in image resolution and color correction. 28mm dia. lens (26mm clear aperture). **$69.95** (2.49)

3 **Series 4000 Photo-Visual Color Filters** (1.25")—Made of purest crown optical glass, dyed in the mass. For increased contrast on the Moon and planets. Thread into virtually all 1.25" eyepieces sold today. Fully coated.

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each **$12.95** (1.79)

Set #1—4 filters: #12 Yellow, #23A Lt.Red, #58 Green, #80A Blue **$42.95** (2.49)

Set #2—4 filters: #11 Yellow-Green, #25A Red, #47 Violet, #82A Lt. Blue **$42.95** (2.49)

Set #3—4 filters: #8 Lt. Yellow, #21 Orange, #38A Dark Blue, #56 Lt. Green . **$42.95** (2.49)

Sets #1 & #2—8 filters **$82.95** (2.49)

Sets #1, #2, & #3—12 filters **$118.95** (3.18)

4 **Series 4000 Moon Filter** (1.25")—Excellent for 4" to 12" telescopes. Reduces Moon brightness by 87%. **$14.50** (2.49)

5 **Series 4000 Nebular Filters**—The very latest in multi-layer interference coating technology, Meade premium nebular filters are guaranteed to be the finest obtainable at any price. Use a Series 4000 Broadband filter to block most forms of light pollution, with minimal attenuation of desired wavelengths. Use a Narrowband filter in heavily light-polluted areas, or for extremely high contrast observing of faint nebulae.

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#911B--Threads on to the rear cell of Schmidt-Cassegrain telescopes. **87.95** (1.79)

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$89.95 (2.79)

MA 12mm-Same as above, but with cord and plug for Meade telescopes with power panels, in place of wireless illuminator.
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.965": $24.95 (2.49) **1.25": $29.95** (2.49)

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Machined sliding cell allows variable projection power in eyepiece-projection photography; permits precise selection of correct photo power in lunar and planetary photography; threaded for filters. Use with T-Mount for your camera.

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Basic Tele-Extender: *(above)* Fixed projection power; use with eyepiece for lunar and planetary photos. **$26.95** (2.49)

Variable Tele-Extender: Sliding cell, with lock, permits wide range of projection magnifications with the same eyepiece.

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2X Telenegative Barlow (1.25")

#122: Doubles eyepiece power with sharp, high-resolution, high-contrast imaging on telescopes of all types. 27mm dia. (26mm clear aperture). Excellent corrections for chromatic and spherical aberrations at all photo-visual wavelengths. Multi-coated. 1.25" **$47.95** (2.49)

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- Meade accessories may be ordered from any Meade Advanced Products dealer. **The following national mail-order dealers carry all Meade accessories in-stock for immediate shipment:**

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Orders: 800-422-7876; Info.: 405-364-0858.

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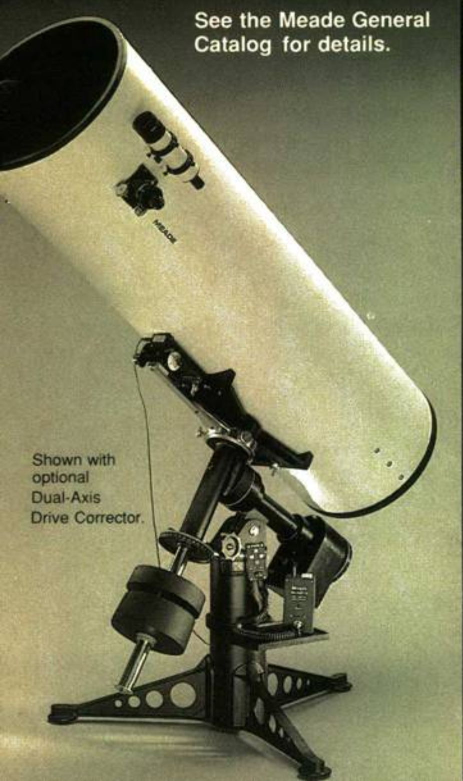

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Now you can buy the most advanced 8" and 10" Schmidt-Cassegrains ever produced, at a price directly competitive with other SCT's offering only a fraction of the features!

Meade LX200 SCT's offer a revolutionary departure from any other SCT's ever made available. Consider the **standard specifications** of these telescopes:

New Heavy-Duty Fork Mounts—The largest, most rigid in the industry. *Meade 8" and 10" LX200 fork mounts yield the lowest damping times of any SC fork mounts available.* Large 4"-diameter polar ball bearings complemented by DC-servo-motor-driven worm gears on ***both*** telescope axes permit observatory-level precision in tracking, guiding, and slewing.

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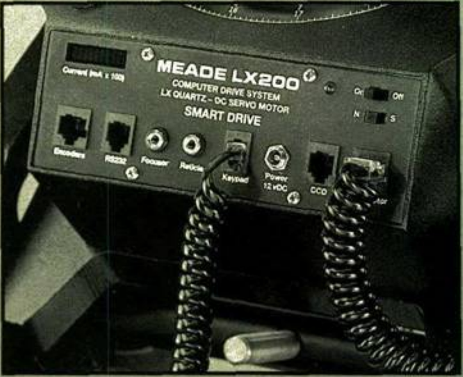
- **Four-speed operation on both telescope axes** simultaneously, including (a) photo-guiding (at **2x** sidereal rate); (b) image centering and microslewing in the main telescope (at **32x** sidereal rate); (c) image centering in the viewfinder (at **2°** per sec.); or fast-slew of the main telescope across the skies (at **8°** per sec.).
- **Pushbutton Electric Slew**—Press RA or Dec slew, east or west, north or south, and the telescope moves at 8° per sec. on both axes. As you near a desired object, flip to 2° per sec. slew, to center the object in the field. The observer need never touch the telescope in moving from one object to another. (Of course, if you wish, the telescope may be moved manually as well.)



- **Digital Readouts** on both axes, read from the handheld Electronic Command Center (ECC).
- **GO TO Capability**—Enter the RA and Dec of an object into the keypad of the ECC, press GO TO, and the telescope automatically slews to the object at 8° per sec., *centering it in the field.*
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- **Permanently programmable (PPEC) Smart Drive**™, capable of reducing periodic drive errors to 5 arc. sec. or less.

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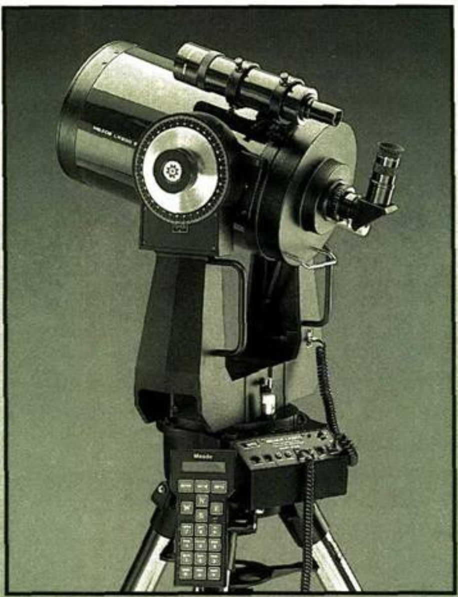

Altazimuth Mode Operation—For all visual observing applications, and for lunar and planetary photography, Meade LX200's may be set up in the altazimuth mode, without any equatorial wedge—just attach the telescope's drive base directly to the tripod, use the fast 1-star alignment procedure, and the telescope's computer actuates 2-axis tracking that keeps objects precisely centered in the field, even at high powers, during the entire observing session. For long exposure photography (longer than about 5 minutes) altazimuth-induced field rotation requires an equatorial wedge, which may be purchased separately.

Fast Polar Alignment—Center two reference stars in the telescopic field and the telescope's computer tells you exactly what telescope controls to actuate for precise polar alignment in the equatorial mode in less than a minute.

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MEADE LX100 SCHMIDT-CASSEGRAINS

Observers not requiring the sophistication of the LX200 electronics may wish to consider an 8" or 10" LX100 model SCT instead. Meade LX100's include the exact same heavy-duty fork mounts of their LX200 counterparts, but with a microfine declination tangent arm control in place of the LX200's motorized worm gear, and with a 2-speed drive in place of the LX200's 4-speed drive; optical tubes and coatings are identical. Standard LX100 features include:

- Handheld Electronic Command Center—With 2-speed operation, **2x** for photo-guiding and **32x** for image centering and microslewing in the main telescope. (With the optional DC-servo declination motor installed, these speeds are operational on both telescope axes.)
- Permanently programmable (PPEC) Smart Drive, as described above.

Complete LX100 and LX200 Telescopes

Specifications: 8" and 10" LX200's—Each complete telescope includes: 8" or 10" SC optical tube assembly (specify f/6.3 or f/10) with super multi-coatings; heavy-duty fork mount, with 4" polar ball bearing, dual-axis 5.75" worm-gears, and multi-function power panel display on the drive base; manual slow-motion controls on both axes; handheld keypad Electronic Command Center, with digital readout display, PPEC Smart Drive, four-speed drive control on both axes, GO TO controller, and 747-object software library; 25 ft. power cords for telescope operation from either 12 v. DC auto cigarette lighter plug or 115v.AC; 8 x 50mm viewfinder with crosshairs; diagonal prism (1.25"); Series 4000 Super Plössl 26mm eyepiece; variable-height field tripod; new deluxe die-cut-foam-fitted carrying case; complete operating instructions.

Specifications: 8" and 10" LX100's—Each complete telescope includes 8" or 10" SC optical tube assembly (specify f/6.3 or f/10) with super multi-coatings; heavy-duty fork mount with 4" polar ball bearing, 5.75" RA worm gear, and multi-function power panel display on the drive base; manual slow-motion controls on both axes; handheld pushbutton Electronic Command Center with PPEC Smart Drive and 2-speed drive control; 25 ft. power cords for telescope operation from either 12v. DC auto cigarette lighter plug or from 115v. AC; viewfinder: 6 x 30mm (8") or 8 x 50mm (10"); diagonal prism (1.25"); Series 4000 Plössl 26mm eyepiece; variable-height field tripod; equatorial wedge (8") or Superwedge (10"); new deluxe die-cut-foam-fitted carrying case; complete operating instructions.

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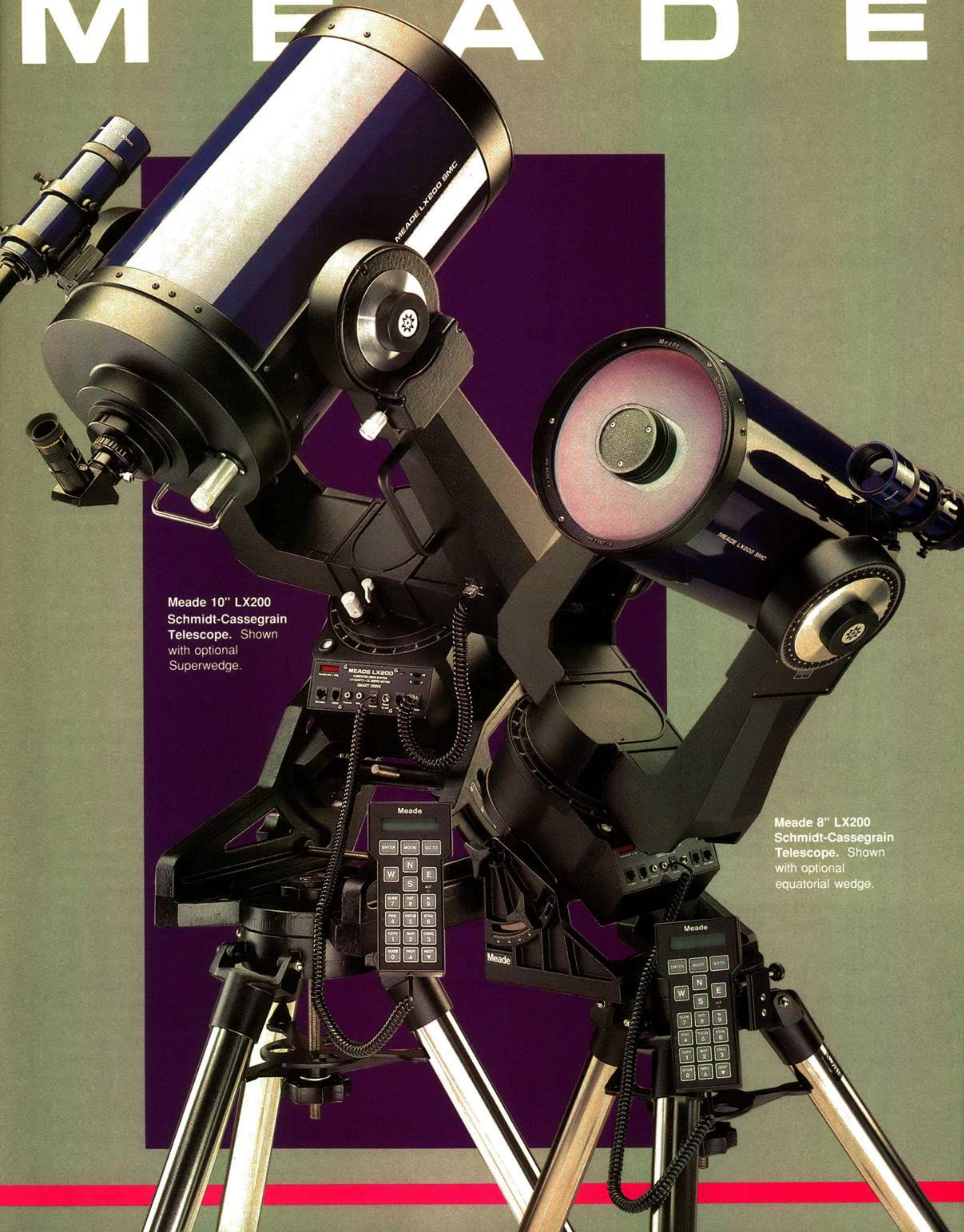
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Basking in the Lunar Rays

I enjoyed Edmund Fortier's article "Explore the Lunar Rays" (April 1992). However, I felt the article should have included the unusual propeller-shaped ray system of Proclus just west of Mare Crisium. Another bright ray system exists in Byrgius A, near the western lunar limb south of Grimaldi. — *Ron Manley, Greenville, South Carolina*

Getting a Leg Up on Footings

Jim Krick's article on Owl Observatory (April 1992) is terrific — it looks like Jim did a great job. Most amateur astronomers want a backyard observatory, and I hope this series will spur them on to accomplish such a great project.

My only question about the article concerns footings. Using 10" concrete pads for the posts seems to be inviting uneven settling from frost because of the inevitable unequal distribution of weight on the pads. A less risky alternative might have been pole-barn construction. — *George Newberger, Akron, Ohio*

Several years ago I built my own observatory using a design similar to Mr. Krick's. I used the same pier-foundation combination without first checking the engineering properties of the soil. My naiveté has turned a once-functional observatory into a storage shed.

Because of my experience, I want to warn others about doing all of your homework before starting construction. The first thing you can do is to check the soil analysis for your area conducted by the U.S. Geological Survey. You might also find this information at a local agricultural extension office or the state highway department.

The problems that I've had with ground alternately shrinking and swelling can happen as a result of soil composition, topography, meteorological variations, or changes in hydrography. If you live in an area where the shrink-swell problem could be extreme, the pier-foundation style of construction used by myself and by Mr. Krick is not the right way to build. — *Doug Kniffen, Warrenton, Missouri*

So Close and Yet So Far

Your news item on the newest, farthest quasar (March 1992) was fascinating. It's quite incredible to think of the sheer immensity of the cosmos. It prompted me to regain an understanding of distances in the universe. Taking 1 light-year as 1 inch, the nearest star system to our Sun lies about 4$^1/_4$ inches away. The extreme outer edges of our solar system, the Oort cloud, lie about 1 inch away. Jupiter lies so close to Earth that you cannot slip a piece of paper between them.

On this scale, our Galaxy measures slightly more than 1.5 miles across. The nearest spiral galaxy, the Andromeda Galaxy, lies at a distance of 31 miles and stretches some 3 miles across. The quasar PC 1247+3406, the one mentioned in your news story, lies 189,394 miles distant — approximately four-fifths of the real distance to the Moon! — *Peter W. Mills, Chatham, Kent, England*

More Nights on Kitt Peak

I was pleased to see Dave Bruning's article "Three Nights on Kitt Peak" (April 1992). The piece provides an accurate feeling of what it's like to observe on Kitt Peak. Smaller telescope users don't yet echo his comment, "Since computers now do most of the work . . . I mostly read fiction. . . . I actually feel a little extraneous at the telescope."

I keep pretty busy while observing. I mainly use smaller telescopes (the 2.4-meter and 1.3-meter telescopes at the Michigan-Dartmouth-MIT Observatory, plus others in the lowly 1-meter class), so I don't have the luxury of a night assistant and have to operate the telescopes myself. Because several computers sit in front of me, I reduce and analyze data as much as possible while I observe. This saves time and possibly reveals serendipitous discoveries for me to observe while I still have telescope time.

Nevertheless, with Dave's 2- to 3-hour exposures, things could get pretty slow. When I'm in a similar situation, I go outside and stargaze. In February I taught myself two new constellations, Leo Minor and Sextans, while the 1.3-meter scope happily made time-resolved spectrophotometric measurements of cataclysmic variables — in Leo Minor and Sextans. Last October, I learned Cepheus and Cetus. I enjoy Mercury, meteors, and the zodiacal light. *Norton's Star Atlas* will never outlive its usefulness! — *Fred Ringwald, Department of Physics and Astronomy, Dartmouth College, Hanover, New Hampshire* ☐

ASTRONOMY welcomes comments and additional information on articles and astronomy in general. Send your letters to ASTRONOMY Letters, P.O. Box 1612, Waukesha, WI 53187. Letters may be edited for length or clarity.

OBSERVING COMPANION

by M. Barlow Pepin

It's a crystal clear evening in October. The setting crescent moon is rock-steady on the horizon, with a distinctive bluish earthshine. Conditions at our club's new observing site are definitely worth the 30-mile drive. It's a good night to search for elusive objects with my new telescope. The 7-inch refractor is a hound dog for faint targets. After setting up and talking about observing with others, I spend a few hours immersed in searching for globular clusters and planetary nebulae.

When the southern Milky Way has finally set, leaving the constellation Cygnus still high overhead, I slew the telescope northeast into Perseus, finding some faint galaxies worth exploring. It's a crisp evening, turning colder by the minute. A hot cup of coffee would be good right now.

I feel my head sinking, but am pulled back to awareness by a voice from the darkness. A new member of the club is standing behind me, carrying a fluorescent lantern with red cellophane taped over it. The thing puts out about 1,000 candlepower and leaks white light all over the place.

"Pretty good seeing tonight, yeah? Can I borrow the eyepiece you told me about to look at Saturn before it sets?"

"Sure, buddy. Anything. Just turn off that lantern."

"Oh, yeah. Sorry." The searchlight is switched off.

The specter departs, clutching my eyepiece. My night vision is gone. I can't see my hand in front of my face.

I'm waiting for my eyes to adapt to the dark, still dwelling on the probable fate of my expensive wide-field eyepiece, when another voice from the darkness asks, "What are you looking at?"

And just when I thought I was set for a peaceful night of solo stargazing . . .

"Nothing special. You can take a look."

The newcomer brushes by me. My night vision is slowly returning. I can barely make out a figure dressed in white.

"So how do I look at something?" she asks. Her voice has an unusual accent.

"Just look into the eyepiece, right here."

I switch on my red penlight. As she bends down to the eyepiece, the faint cone of light illuminates a pristine profile. A thin, golden belt gleams at the waist of her white shift. On a chilly night like this, she's wearing sandals. Definitely not an experienced observer.

"Everything is swimming in a fog!"

"The telescope must not be in focus for you. Just turn this knob very slowly until the stars get as small as possible."

"Oh, now it gives a very good view! It looks like two tiny clouds dancing among the stars."

"You're right. It's two galaxies in the constellation Perseus. They're clouds of stars, like the Milky Way."

"Yes, I know about the Milky Way — I didn't know there were others, though. I've never looked into this kind of magic glass."

This makes me laugh. "Well, they're good optics, but I don't think it's magic."

She steps away from the telescope in the darkness, tangling her foot in the power cord. I reach out to keep her from falling and she catches my wrist. Her fingers are cold. I can feel her shivering.

"Excuse me, I'm so clumsy," she apologizes.

"You must be really cold."

"Brrrr, yes! I should have worn my winter cape."

"Here, put on my jacket if you like. This sweater is warm enough for me."

I hold up the jacket and she quickly puts in on.

"Thank you. That's much better."

"Are you here alone?" I ask her.

"Yes. I couldn't talk any of my sisters into coming down."

"Big family?"

"Father, mother, and six younger sisters. Not very exciting. My father is strict, so I don't leave very often. Will you show me some more things in the sky?"

I check to see that my telescope is still polar aligned. She asks, "What are you looking at?"

"I have to point this little telescope at

[continued on page 16]

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David McGough, Millington, N.J.

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"Careful star-testing of the 10.1" Odyssey Compact I received last March and of the 10.1" my neighbor Doug Barnes picked up in mid-October suggests a high level of quality control which is astonishing. Diffraction patterns are virtually interchangeable, and both scopes show textbook optical results (both in-focus and out-of-focus)."
Lee Johnson, Coquitlam, B.C. Canada

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"In amateur astronomy for over 35 years and I have seen my share of all kinds of telescopes, good and bad. To say the least, the Odyssey 1 outperforms any thing that I have seen!!"
Richard Ziegler, Maumee, Ohio

"There is not another telescope of equal size in our club that can touch the clear image and ease of operation that Odyssey 1 provides."
Mark Davenport, Pinellas Park, Fla.

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"I've only had a chance to view once so far, but am thoroughly thrilled with it. Viewing from a (Santa Barbara, Ca.) residential front yard, the Orion Nebula was indeed a treat – reddish tinges on the predominating green, with many subtle wisps and lanes very clear. The Andromeda Galaxy was surprisingly bright, as was its companion." David Broad, Santa Barbara, Ca.

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If you are thinking about buying a Celestron telescope, Orion is the place to buy it. We've sold thousands of Celestron telescopes to amateur astronomers across the USA. Our low, low prices and special accessory packages can really save you a bundle! Whether you are considering a big telescope or a small one, or a binocular or accessory, chances are Orion has just what you are looking for. And we probably have it in stock for immediate delivery, too!

Celestron telescopes are available with a variety of mounts, including German-style equatorial or fork mounts, with a wide range of available drive systems including the renowned CompuStar computer-controlled mount. A huge selection of models up to 14" in aperture, in all price ranges, available for immediate delivery!

Schmidt-Cassegrains — Celestron pioneered these fantastic instruments, and has an enviable reputation for building unsurpassed, exquisitely fine Schmidt Cassegrain optical systems.

Refractors — Celestron's wide range of refractor models covers the full range of apertures where the refractor is well suited to portable use, up to 102mm diameter. Models include the incredible 102mm Fluorite apochromat, ideal for the advanced refractor enthusiast.

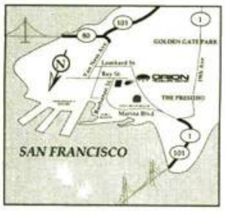
Reflectors — Celestron's popular reflector telescopes feature superb optical performance and full-featured, precision equatorial mounts which permit a full complement of optional accessories including electronic drive systems.

Thinking about your first telescope?

Call our telescope experts Toll Free with any questions you may have. Please don't be embarrassed if you don't understand everything or are a bit overwhelmed. We've been helping first-time buyers for 17 years, and we're happy to help smooth your path to this fascinating hobby!

When You're in the San Francisco Bay Area, Visit One of Our Three Unique Retail Stores.

America's biggest & best selection of telescopes, binoculars & accessories. Now 3 convenient Northern California locations!



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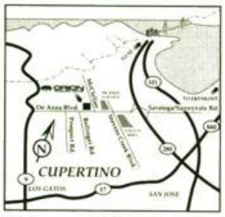

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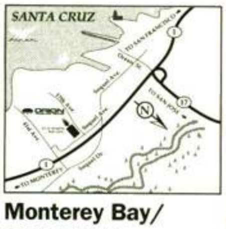

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Orion Refractors on Sale!
Up to $50 off! Free Edmund Sky Guide and red lens flashlight.
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Sky Explorer 80 Refractor

Perfect for planetary and lunar observation. Equatorial mount, loaded with accessories: two eyepieces, 2x barlow, erecting prism, 6x30 finder, sun screen, moon filter, star diagonal, tripod and accessory tray.

#21094 ~~$539~~ ***Sale $489*** (32.66)

Sky Explorer 60 Refractor

Ideal for lunar and planetary study, plus it's a powerful terrestrial telescope. 900mm f.l, 6x30 finder; star diagonal ; two eyepieces, equatorial mount; setting circles; tripod; and lighted accessory tray.

#21093 ~~$349~~ ***Sale $299*** (13.22)

TeleVista 60mm Refractor

Equally at home viewing the rings of Saturn or boats across the bay. Two quality eyepieces, all metal optical tube and yoke mount, finder scope, adjustable tripod, diagonal prism.

#21092 ~~$199~~ ***Sale $169*** (8.97)

SpaceProbe 4.5 Reflector

Great 4.5" f/8 reflector, ideal for planetary and deep space. Equatorial mount, slow motion controls, setting circles. 6x30 finder plus 25mm (36x) and 9mm (100x) 1.25" eyepieces. Deluxe tripod.

#9099 ***$399*** (22.19)

OmniVista 60 Multipurpose Refractor

High performance 420mm f/7 60mm rich field scope. Makes a great compact astrograph, telephoto lens, spotting scope, or guide scope.

#9090 ***$249*** (5.94)

Ultrascan 80

Hot ED apochromat, 80mm f/6.25 fantastic optics with great 2" focuser, 6x30 finder. Eyepiece/diagonal extra.

#9080 ***$444*** (6.89)

Tele Vue

Orion is your # 1 Source for TeleVue! See our catalog for Tele Vue scopes and accessories.

- **Plössl Eyepieces**
- **Nagler Eyepieces**
- **Panoptic Eyepieces**
- **Wide Field Eyepieces**
- **Systems Mount**
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Genesis Refractor

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50mm Observer™ Binoculars

Fine quality, moderately priced binoculars, excellent for both astronomy and daytime observation. Fully coated optics, rugged ribbed rubber covering for a good grip. Both have a 7° field of view.

New Low Price!
7x50 #9620, *10x50* #9623. ***$79.95*** (4.44)

50mm Explorer™ Binoculars

Our newest high performance binoculars with BAK-4 prisms and Multi-Coatings. Great for both astronomy and daytime observation. Comfortable ergonomic body design.

New Low Price!
7x50 #9306, *10x50* #9308 ***$99.95*** (4.71)

50mm Adlerblick Binoculars

Incredible wide field eyepiece design, Fully Multi-Coated, BAK-4 prisms, and best special glass objective lenses make the 7x50 Adlerblick the arch rival of European brand binoculars selling for 3-4 times the price. Orion buys direct, saving you money. Includes deluxe hard case, lens caps and straps.

7x50 #9612 ***$279*** (5.28)
10x50 #9610 ***$269*** (5.28)

Orion® 8x56 Mini Giants

56mm objective lenses gather over 2.5x the light of ordinary 7x35 binoculars. Perfect for viewing faint celestial objects, daytime viewing. Best Multi-Coated BAK-4 optics. 6° field of view. Standard model 33 oz. Rubber Armored for protection from bumps. Weighs 37 oz.

Rubber Armored Model #9627 ***$149*** (5.07)
Standard Model #9504 ***$149*** (4.71)

Orion® 10x70 FMC Giants

The standard for hand-holdable astronomy binoculars. Fully Multi-Coated. 33% lighter—weighs only 58 oz.—yet the same brightness and 7mm exit pupil as our 11x80 MC model. Superior 'BCF' body design. Includes: soft rubber eyecaps, tripod mounting adapter, durable hard carrying case, lens caps and straps.

#9501 ***$299*** (6.97)

80mm FMC Giant Binoculars

20% more light transmission than ordinary "fully coated" binoculars. Fully Multi-Coated optics and superior BAK-4 prisms provide fantastic contrast and greatly improved edge sharpness.

11x80 MC- Brightest, widest field available. Ideal for deep-space observation under dark skies. Hand-holdable.
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16x80 MC- 45% higher power, excellent for astronomy and daytime observation. Tripod recommended.
#9496 ***$379*** (8.05)

20x80 MC- Highest power model perfect for smaller deep-space objects and long range daytime views. Tripod required.
#9498 ***$389*** (8.05)

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Gigantic, almost 4 inch, lenses gather 156% of the light of 80mm binoculars. Individual eyepiece focus, fully multi-coated optics and BAK-4 prisms. Comes with tripod mounting plate and metal-clad case. 14x magnification, field of view 3.3°, exit pupil 7.0mm, weight 7.5 lbs., height 13.5".

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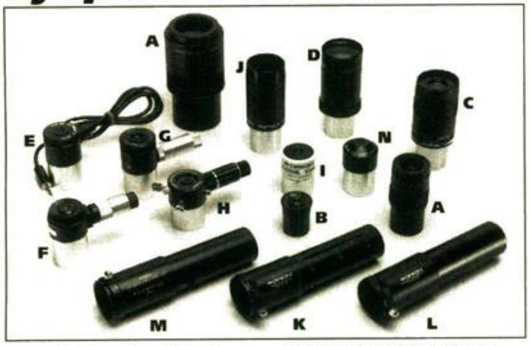

A 77° Field UltraScan™ Eyepieces

Fantastic panoramic eyepieces—rival 'famous' brands at a fraction of the price! Superb coatings and optics.

1.25" UltraScan Eyepieces

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12mm #8421 **$109** (3.67)

15mm #8422 **$129** (3.67)

19mm #8423 **$139** (3.67)

30mm 2" UltraScan Eyepiece #8424 **$219** (4.71)

40mm 2" UltraScan Eyepiece 68 degree apparent field, #8425 **$199** (3.67)

B Explorer .965" Eyepieces

Fine quality Multi-Coated eyepieces.

.965" Orthoscopic Eyepieces 5mm #8580, 7mm #8581, 9mm #8582, 12.5mm #8583

$42.95 ea. (2.98)

.965" Kellner 18mm #8584, 25mm #8585
.965" Achromatic Huygenian 40mm #8586

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C UltraZoom™ 7–21mm

The finest zoom you can buy for your 1.25" telescope. An excellent choice for astronomy or terrestrial observing. 65°-35° field. Fully coated.

#8556 **$139** (3.67)

D Superb Ultrascopic™ Eyepieces

Unlike other premium eyepieces, Orion Ultrascopics offer complete multi-layer coatings on ALL surfaces, for superior light transmission and contrast. Modern 5- and 7- element designs for pinpoint star images and breathtaking detail. Wide 52° field of view. Guaranteed to beat other brands selling for much more! Unsurpassed high-performance design!

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20mm #8566, 15mm #8568, 10mm #8570, 7.5mm #8572

$64.95 ea. (3.45)

Wide Field 5-element

25mm #8564 **$79.95** (3.45)

30mm #8562 **$84.95** (3.45)

35mm #8560 **$89.95** (3.45)

High Power 7-element *—Long Eye Relief*
5mm #8574, 3.8mm #8576

$89.95 ea. (3.45)

E 12mm Kellner Illuminated Reticle Eyepiece

12mm Kellner eyepiece with cable plugs into power panel drive bases, and most drive correctors with illuminated reticle output for polar alignment and guiding.

#8482 **$69.95** (3.45)

F 9mm Illuminated Reticle

9mm Orthoscopic eyepiece with wireless adjustable brightness illuminator. Bull's-eye within three concentric circles helps measure limits of acceptable guiding error.

#8488 **$119** (3.67)

G Orion® 12.5mm Plössl Illuminated Reticle Eyepiece

This new 12.5mm 4-element Plössl offers unprecedented eye relief and observing comfort during long astrophoto exposures. The battery operated integral illuminator has fully adjustable brightness. Features double crossline reticle.

#8484 **$99.95** (3.45)

H 6mm Illuminated Reticle

6mm Orthoscopic design for high power guiding, unique X-Y adjustable reticle positioning for easy guide star alignment. Wireless LED illuminator has adjustable brightness.

#8487 **$149** (3.67)

I Orion Plössl Eyepieces

Orion Multi-Coated Plössl eyepieces are fine performers at an amazingly low price. Precision 4-element Plössl lens elements mounted in sturdy aluminum barrels. Available in 12mm, 18mm, or 25mm focal lengths, with 1.25" barrels. Buy all three for less than some single eyepieces!

12mm-#8596; ***18mm***-#8597; ***25mm***-#8598

$42.95 ea. (2.98)

J MegaVista™ Wide Angle

Incredible Fully Multi-Coated high-transmission 7-element eyepieces with integral rubber eyeguard and long eye relief.

10.5mm—An incredible 67° field for outstanding planetary or deep space performance.

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16.8mm—Outstanding high-contrast eyepiece with stunning 70° field ideal for deep space.

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K VariPower™ 2-3x Barlow

Our best barlow fills the gaps in your eyepiece collection. Internal lens cell slides easily to adjust magnification. Quality optics provide excellent sharpness, contrast and brightness. Works with 1.25" diameter eyepieces and right-angle diagonals.

#8748 **$59.95** (3.45)

L Ultrascopic 3-Element Barlow

Fully Multi-Coated 3-Element Barlow lens provides superior imaging with precise color correction at three wavelengths. For maximum light transmission and highest contrast, we have used the finest quality multi-coating on each air to glass surface. 1.25" diameter.

#8750 **$54.95** (3.45)

M Fully-Baffled Barlow Lens

Fully internally opaqued and baffled to block stray light for noticeably higher contrast. Large 27mm multi-coated 2-element lens provides 2x magnification with any 1.25" eyepiece.

#8746 **$44.95** (2.98)

N Explorer 1.25" Eyepieces

Guaranteed high-performance, Multi-Coated parfocal eyepieces with great performance. Each carefully selected series has been chosen to provide a sensible progression of magnifications. Threaded for filters. Internally blackened to prevent stray light reflections.

Kellner Eyepieces*—Fine Performance*
6mm #8536, 9mm #8538, 12mm #8540, 18mm #8508, 25mm #8510, 40mm #8512

$34.95 ea. (2.98)

Orthoscopic Eyepieces*—Excellent Performance*
5mm #8500, 7mm #8502, 9mm #8504, 12.5mm #8506, 18mm #8524, 25mm #8526

$44.95 ea. (2.98)

Filters

Color Eyepiece Filters

Highest quality precision-ground optical glass. Fully anti-reflective-coated. Piggyback precision aluminum cells. Solar system observations are dramatically improved by Orion colored filters. Thread one into the barrel of any standard eyepiece. Can also be threaded directly into a universal camera adapter.

.965" Basic Set of 4 Filters Includes #80A Blue, #58 Green, #25 Red, #15 Yellow.

#5510 **$34.95 set** (2.98)

1.25" Basic Set of 4 Filters #5514
Includes #80A Blue, #58 Green, #25 Red, #15 Yellow.
1.25" Expansion Set of 4 Filters #5516
Includes #21 Orange, #47 Violet, #11 Yellow-Green, #82A Very Pale Blue.
1.25" Advanced Set of 4 Filters #5570
Includes #8 Light Yellow, #23A Light Red, #38A Deep Blue, #56 Light Green.

$39.95 set (2.98)

More Color Eyepiece Filters

Deluxe Set of 8 Filters for 1.25" Includes all the filters in our basic and expansion filter sets.

#5517 **$74.95** (3.45)

Full Set of 12 Filters for 1.25" Includes Basic Set, Expansion Set, Advanced Set.

#5575 **$109** (3.67)

Individual 1.25" Filters- #80A Blue (#11040), #58 Green (#5540), #25 Red (#5536), #15 Yellow (#5532), #21 Orange (#5534), #47 Violet (#5538), #11 Light Yellow-Green (#5530), #82A Very Pale Blue (#5544), #8 Yellow (#5571), #23A Light Red (#5272), #38A Deep Blue (#5273), #56 Light Green (#5274)

$11.95 ea. (2.43)

Moon Filters

Cuts 87% of the light from the Moon. Reduces glare by uniformly reducing light transmitted over the entire spectrum.

.965" #5664 **$13.50** (2.43)

1.25" #5662 **$13.50** (2.43)

SkyGlow™ Light Pollution Filters

Enhance your viewing of faint deep sky objects with the best broadband light pollution filter you can buy. Our SkyGlow absorbs frequencies emitted by city lights, allowing transmission of the rest of the visible spectrum, yielding dramatic results.

SkyGlow Broadband Filters—Photographic and Visual
For use in slight to moderately light polluted areas.
1.25" Broadband Filter–fits 1.25" eyepieces.

#5660 **$59.95** (3.45)

Schmidt-Cassegrain Broadband Filter–fits rear cell of Meade & Celestron SC scopes.

#5658 **$79.95** (3.45)

52mm Broadband Filter–For 52mm camera lenses, adapter rings available for other diameters.

#5668 **$79.95** (3.45)

SkyGlow UltraBlock Filters–Visual Only
For severely light polluted areas and faint nebulae.
1.25" UltraBlock Filter–fits 1.25" eyepieces.

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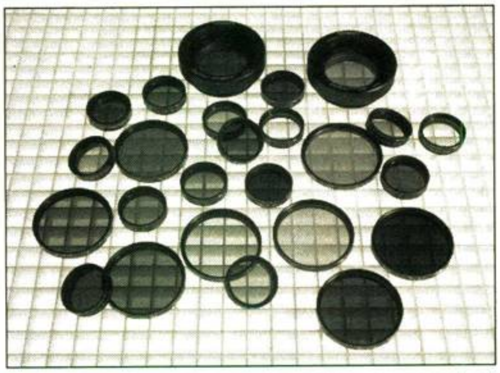
Schmidt-Cassegrain UltraBlock Filter–fits rear cell of Meade & Celestron SC scopes.

#5656 **$119** (3.67)



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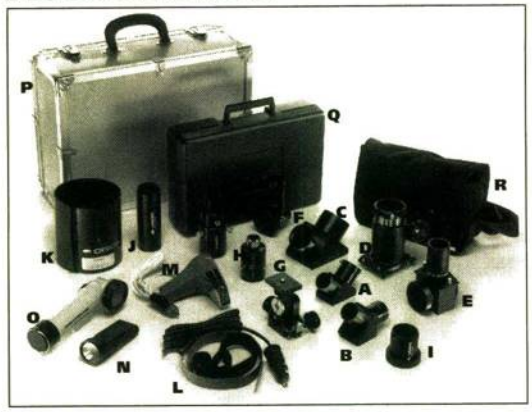

A Star Diagonal Prisms

1.25" Star Diagonal Multi-Coated.

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.965" Star Diagonal Coated optics.

#8761 **$24.95** (2.98)

B 45° Erect Image Diagonals

.965 Diagonal #8759 **$69.95** (3.45)

1-1/4" Diagonal #8753 **$69.95** (3.45)

Size-Adapting Hybrid Diagonal #8755 **$69.95** (3.45)

C 2" Mirror Star Diagonal

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D Rack & Pinion Focusers

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1.25" Focuser #13017 **$42.95** (2.98)

2" & 1.25" Focuser #13019 **$79.95** (3.95)

E Orion® UltraGuider™

Advanced features at a low price. Use with Meade or Celestron SC. Easily adjustable prism. Ultra-precise helical focus of your eyepiece, adjustable camera focal plane position.

#5139 **$119** (4.19)

F Orion® Premium Off-Axis Guider

High performance, Multi-Coated, precision anodized. Low Orion price!

#5144 **$49.95** (3.45)

G Basic Camera Adapters

Combination Eyepiece Projection Tube and Prime Focus Adapter for refractors and reflectors with 1.25" eyepiece holders. Use with T-Ring (sold separately).

.965" #5268 **$24.95** (2.98)

1.25" #5264 **$29.95** (2.98)

H Vari-Power Camera Adapter

Unique sliding barrel design allows variable projection distances during eyepiece projection photography, eliminating the need to change eyepieces when magnification changes.

#5262 **$39.95** (2.98)

I Orion® T-Adapter for SC

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#5116 **$24.95** (2.98)

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For high powered photography with your Meade, Celestron 4", 8", 10", 11", 14" Schmidt-Cassegrain.

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Attaches to your photo tripod pan head and gives you two slow motion control knobs to make precision adjustments in altitude and altazimuth.

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K FlexiShield™ Dew Caps

Eliminate dew problems with FlexiShield! Better performance, more rugged, and easier storage than rigid dew caps. Forms into a tube with the velcro closure, opens flat for easy storage and transportation. Fits your telescope tube snugly, with wide rubber padding and full length velcro closure—needs no screws. Models to fit most telescopes.

8" Celestron/Meade Schmidt-Cassegrains

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Plus nine other models for scopes 3.5" to 14"—Call toll-free!

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Orion's Dew Zapper is a sure-fire cure for dew problems on your 8" or 10" Celestron or Meade Schmidt-Cassegrain telescope. Dew Zapper gently replaces lost heat, bringing the corrector plate temperature slightly above air temperature.

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AC Model #3504 **$44.95** (2.98)

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DC Model #3506,
AC Model #3508 **$49.95** (2.98)

M Dew Remover Gun

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#5601 **$17.95** (2.78)

N Starlite Red LED Flashlight

The Starlite is the only adjustable-brightness night-vision red flashlight. Lifetime solid-state LED can't burn out. Extra efficient electronic circuit for long battery life. Uses one 9-volt battery (not included).

#5714 **$24.95** (2.43)

O Astronomer's Flashlight

Indispensable and indestructible. Has special night-vision red filter and a diffusion lens for even illumination. An essential addition to your astronomy accessories. Requires 2 D-cell batteries (not included).

#5701 **$9.95** (1.79)

P Deluxe Accessory Cases

Keep accessories and camera safe and clean. Diced foam inserts can be tailored to your needs. Sturdy handle, two latches, key.

Regular Case: 16"x12"x61/2"

#5920 **$59.95** (6.67)

Large Case: 191/2"x12"x61/2"

#5921 **$69.95** (7.10)

Q Deluxe Eyepiece Case

Organize and protect your valuable eyepieces and other accessories. This durable case with double hinges holds up to 10 eyepieces plus barlow. Die cut foam insert for snug secure fit. O.D. 8-1/2"x12-1/2"x3-1/8".

#5913 **$17.95** (2.78)

Field Tripod Tote Bag

Designed for the field tripod with padded insert to separate wedge from tripod during transportation. Specifically made for wedge combinations of Schmidt-Cassegrain telescopes up to 10" aperture. Allows storage without changing polar alignment. This blue bag is made of tear, rip and mildew resistant 100% Cordura nylon.

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Observer's Chairs

Make observing more comfortable and enjoyable with one of these great chairs.

Standard Model—Has adjustable height center column and padded vinyl seat. Folds for easy storage.

#5935 **$39.95** (4.79)

Deluxe Model—Is much heavier-duty, built for professional musicians. Extra thick padding, wide footprint. Adjustable and disassembles for storage.

#5934 **$89.95** (8.02)

R 12 Amp Hour Porta Pac Battery

Ideal for operating your telescope plus higher power-consuming accessories such as an Orion Dew Zapper.Battery is encased in high impact polystyrene. Carrying case of Cordura nylon with shoulder strap and handle. Wt. 10 lbs.

#2354 **$109 ea.** (8.97)

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the North Star so I can find other objects more easily in the larger telescope."

I then give the standard star party tour. She seems very impressed by the Andromeda Galaxy. The new telescope is performing fantastically. We can see the dark stretch of Andromeda's dust lane. Impossibly, some of the galaxy's stars even seem resolved. We wander for a long time through the star clusters of Auriga. The globular cluster M15 is almost on the horizon, but it still glows like a scoop of diamond chips. It's an exceptional night for observing. The seeing is great and I've never noticed such complete transparency.

It's time for a break. I pour coffee from my thermos into two styrofoam cups and hand her one. My eyes are so adapted to the dark that the white cups seem to glow.

"Thank you," she says sipping her coffee. "This drink is bitter, but good. That northern star, Polaris you called it? It seems higher in the sky than I remember."

"You must be from the South somewhere, it would be lower from there. I notice that you have an accent. Where are you from anyway?"

"Greece. But I haven't been back there in a long time. I haven't looked up at the sky in a long while either."

She puts her cup on the grass and goes back to the telescope. It is still tracking the Orion Nebula as the constellation rises higher. Sitting motionless at the eyepiece, she starts singing in a soft voice. The Greek words sound strange, the tune unlike any I've ever heard before.

"What's that?"

"It's a song about the sky my father taught me. It goes, 'Orion is still, he hunts no more in the forests of Boeotia.'"

The hours pass unnoticed. After finding everything I can think of, my companion still asks for more and more objects. We waste about ten minutes looking for the elusive Rosette Nebula in Monoceros. She tosses her head and laughs. The merry sound echoes across the field. I sense heads turning at the other telescopes.

"Well, I don't need to see everything, but I want to see one more thing in the sky."

"What do you want to see?"

"That little cloudy star cluster over there."

"Okay. That's the Pleiades."

I swing the dew-covered telescope over to the west. As I frame the cluster in the finder, she whispers, "Notice anything?"

"What do you mean?"

"I want you to look very carefully in your finding telescope. Do you notice anything . . . different?"

I force myself to concentrate on the view in the finder, on the sparkling star cluster I've observed a hundred times. She's right. Something is different. The Pleiades are out of shape. One of the 4th-magnitude stars is gone. The occultation of a bright Pleiad would have been publicized. We would all be watching, waiting for it. I hastily check the finder. There's nothing blocking the lenses. Six bright stars stare back at me. I look up. The difference is obvious, even to the naked eye.

"You're right! But how could a girl like you notice that? You said you hardly ever look at the sky. I've got to let somebody else know about this!"

I start to yell for another observer to confirm the incredible event. Then I feel her hand on my shoulder.

"Stop. Please don't tell anyone! And please don't call me 'girl.' My name is Maia, and I'm much older than you are. Besides, I said I hardly ever look *up* at the sky. I look down from it all of the time."

Suddenly, a fragment of mythology from a star guide leaps into my mind: Maia, the oldest of the Pleiades, the most beautiful daughter of Atlas. But what . . . ? A sense of unreality creeps over me, and I feel my brain start to go supernova. Maia senses my panic. She touches my shoulder reassuringly.

"Don't worry," she whispers. "I can go back up, before anyone notices, or believes what they are seeing. My sisters will be worried, though. I've got to go now. I will come back to see you again, after dark sometime."

A cold blast of wind comes out of nowhere, stinging my eyes. The telescope rattles on its mount. There is a drumming, rushing sound, like doves taking off. Then silence. When I open my eyes, I'm sitting on the ground. Maia is gone. It's cold. Trying to shake off the feeling of shock, I get up and line my telescope up with the little group of stars sinking in the west. My hands are shaking. Seven bright stars sparkle in the eyepiece; nothing unusual. One of them flickers slightly. What a dream. As I look away I see my jacket lying on the grass. There is something bright resting on it. I pick it up. A slender, braided golden belt gleams in my hand. I stare at the Pleiades until dawn washes its light away. The old constellations continue their eternal motion as pale light slowly grows in the east. ☐

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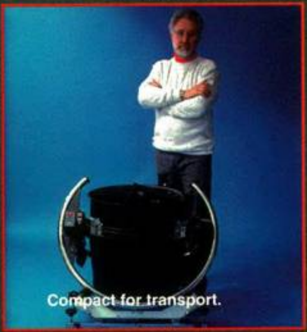

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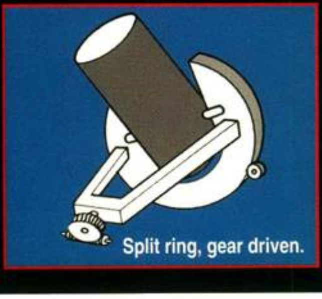

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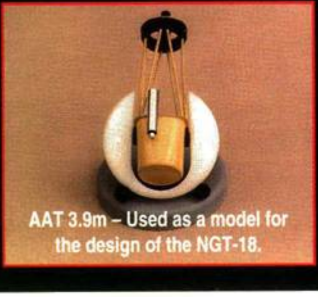

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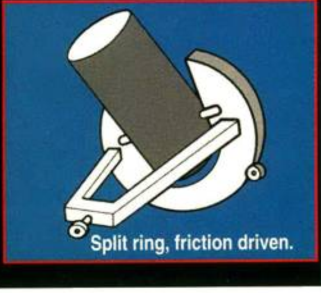

Split ring, friction driven.

HOT NEWS

Big Bang Created Ripples in the Fabric of Space

Random ripples permeate space and may be the primordial seeds from which galaxies formed early in the universe's history. The fluctuations are only 0.001 percent warmer or cooler than the 2.73 kelvins of the cosmic background radiation. Lawrence Berkeley Laboratory scientists found the ripples while analyzing hundreds of millions of measurements taken by the Cosmic Background Explorer (COBE).

The ripples may answer a question that has plagued astronomers for decades. Matter in a smooth universe would take too long to condense and form galaxies. But according to George Smoot, leader of the discovery team, "The fluctuations were produced at the moment of creation, when the universe was so small that there wasn't enough room for a single proton." The size of the ripples agrees with the predictions of inflationary universe models. Further details will appear in the August issue.

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VIVID COLORS HIGHLIGHT this first true-color image of a cometary globule. These objects are small clouds of interstellar gas and dust in our Galaxy within which stars apparently form. The "cometary" description refers to the appearance of these globulars. They show tenuous tail-like structures drawn out by the interstellar gas flowing around them.

A BLACK HOLE FOR M32

Tod R. Lauer/NASA

A MASSIVE BLACK HOLE LURKS in the core of the nearby elliptical galaxy M32, shown here in an image taken with HST's Wide Field/Planetary Camera. The view extends 175 light-years on a side; the grainy appearance near the borders is due to HST's resolving individual stars in M32.

A black hole containing 3 million times as much mass as the Sun lies at the center of the nearby elliptical galaxy M32. That's the dramatic conclusion drawn from new high-resolution images of the galaxy taken with the Hubble Space Telescope (HST). Astronomers Tod Lauer of the National Optical Astronomy Observatories, Sandra Faber of the University of California, Santa Cruz, and other members of HST's Wide Field/Planetary Camera Imaging Team based their conclusion on the extreme concentration of stars toward the center of M32 — a gravitational "signature" of a massive black hole.

Visible in small backyard telescopes, M32 is a fairly small and compact elliptical galaxy, containing some 400 million stars within a diameter of 1,000 light-years. At a distance of 2.3 million light-years, it is one of the Milky Way's closest neighbors, a satellite galaxy to the great Andromeda Galaxy (M31).

Astronomers have suspected since 1987 that M32 harbors a black hole. That's the year ground-based observers first noticed an abrupt increase in the orbital velocities of stars near the galaxy's center. But ground-based images do not have enough resolution to detect the effects of a massive black hole on the structure of M32.

The new HST images, however, show the galaxy's nucleus in clear detail. Lauer, Faber, and their colleagues found that the density of stars in the nucleus increases steadily toward the center, with no signs of leveling off. This distinctive "cusp," similar to one found in the giant elliptical galaxy M87, fits predictions of what a massive black hole should do to the central structure of a galaxy.

"This is the densest stellar system known to astronomers," says Lauer. "The density of stars at the center of M32 may be over 100 million times greater than the distribution of stars in the neighborhood of the Sun. A visitor to a planet near the center of M32 would see a starry night sky so saturated with stars that their combined light would be brighter than 100 Full Moons. The night would never get darker than mid-twilight on Earth."

The proposed black hole at the center of M32 is roughly 1,000 times smaller than the black hole that might exist at the heart of M87. Another key difference between the two black hole candidates is that M32 shows no signs of any nuclear activity, while M87 possesses an energetic jet seen at both optical and radio wavelengths. This means that the black hole in M32 is not now accreting significant amounts of matter. The new results thus open up the possibility that inactive black holes may be quite common at the centers of galaxies.

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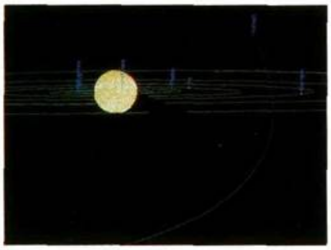
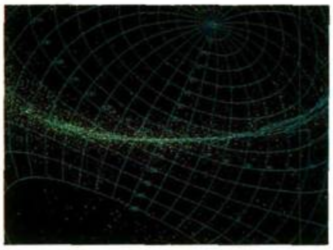


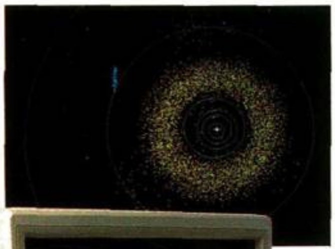
Jupiter expelling comet Lexell from solar system in 1779.

Earth and Moon in Taurus, 16 Oct 2000.

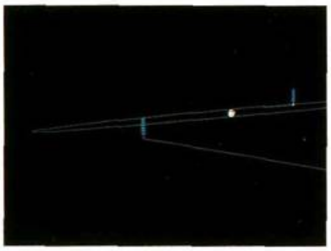


Celestial Skymap with asteroids along the ecliptic.

Polar view of asteroid belt – Jupiter and the Trojan asteroids.



Asteroid 1991BA passing close to Earth. 18 Jan., 17.5h, 1991.



Saturn slipping behind the moon. From Osaka Japan, 8 Oct. 1962.

Lunar eclipse of 9 Feb. 1990, near maximum.

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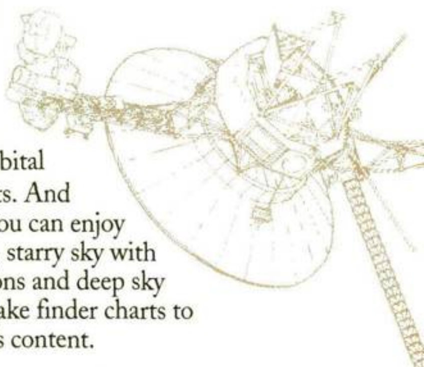

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GAMMA RAYS FROM BL LACS

The Compton Gamma Ray Observatory (GRO) has detected for the first time gamma rays pouring from three BL Lacertae objects — a class of active galaxies known for being very luminous and highly variable in energy output. The observations, made by the Energetic Gamma Ray Experiment Telescope (EGRET) on the observatory, imply that high-energy gamma rays contribute significantly to the total luminosity of these objects.

The results were announced by EGRET's co-principal investigators, Carl Fichtel of Goddard Space Flight Center and Klaus Pinkau of the Max Planck Institute for Extraterrestrial Physics. The telescope observed the BL Lacertae objects (or BL Lacs for short) designated MK 421, 0537–441, and 0716+714, which lie in the constellations Ursa Major, Pictor, and Camelopardalis, respectively.

BL Lacs share many similarities with quasars. They not only are luminous and variable, but also possess high redshifts, which implies that they are very far away. The new observations now add another level of similarity, because GRO had already detected gamma rays emanating from six quasars. The new gamma-ray observations support the hypothesis that BL Lacs, like quasars, are powered by supermassive black holes.

HST IMAGES REMOTE GALAXY CLUSTER

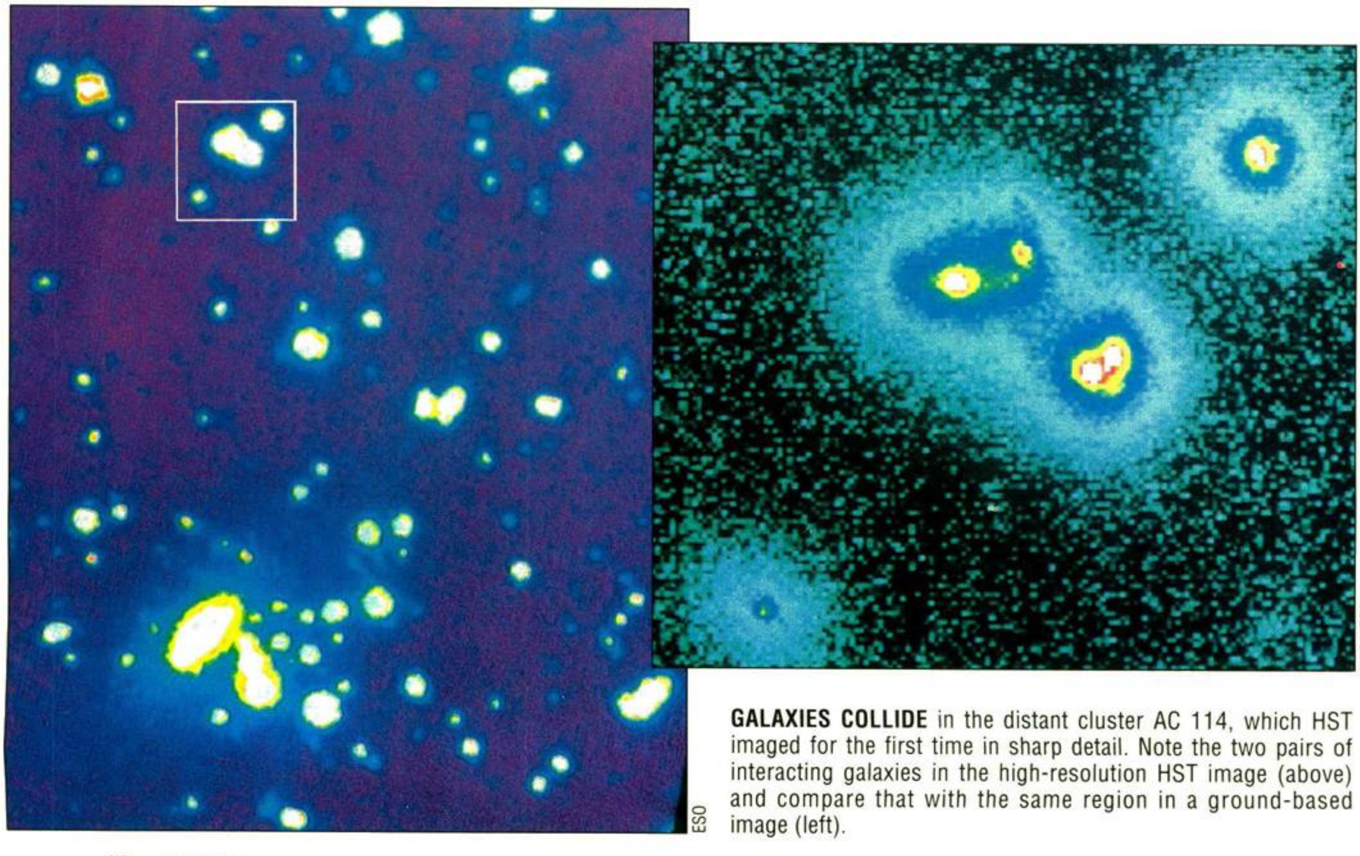
New images from the Hubble Space Telescope (HST) are helping astronomers understand the exotic environments of galaxy clusters. Colliding galaxies, gravitational lenses, and dark matter are just some of the phenomena that have come under the penetrating eye of HST.

A team of researchers led by Richard Ellis of the University of Durham in England has used HST to observe a particularly distant cluster of galaxies. The cluster, designated AC 114, lies over 4 billion light-years away, which means we see the cluster as it was more than 4 billion years ago. HST's superb resolution (some ten times sharper than possible with ground-based telescopes) opens up the realm of distant galaxy clusters to detailed scrutiny.

Astronomers know little about the nature of galaxies so much younger than our own. One question they seek an answer to is how the different types of galaxies formed. One group thinks that spiral, elliptical, and irregular galaxies appear different because the conditions present at their birth were different. A second group thinks that interactions among galaxies in clusters can transform one type of galaxy into another. Though some indirect evidence indicates that such transformations have taken place, the acid test is to examine the structure of galaxies long ago.

That's where the HST images come in. They show a remarkable degree of interaction among the members of AC 114, with bridges of material connecting many galaxy pairs. The researchers conclude that a high proportion of galaxies undergo major changes in their properties as a result of their location in dense clusters. By using HST to examine clusters at even greater distances (and thus longer look-back times), astronomers will be able to directly "watch" the evolution of galaxies.

A second team of astronomers led by Ellis used the high-resolution HST images of AC 114 to study dark matter in the cluster. Dark matter is material that gives off no light and can be detected only through its gravitational effects. It is important because astronomers believe it constitutes 90 percent or more of the mass in the universe.



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NASA/ESA

GALAXIES COLLIDE in the distant cluster AC 114, which HST imaged for the first time in sharp detail. Note the two pairs of interacting galaxies in the high-resolution HST image (above) and compare that with the same region in a ground-based image (left).

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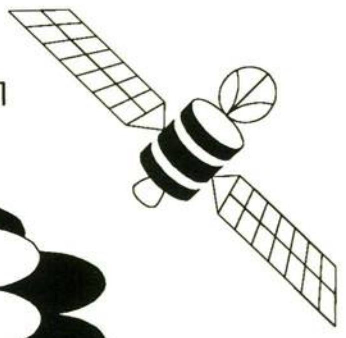

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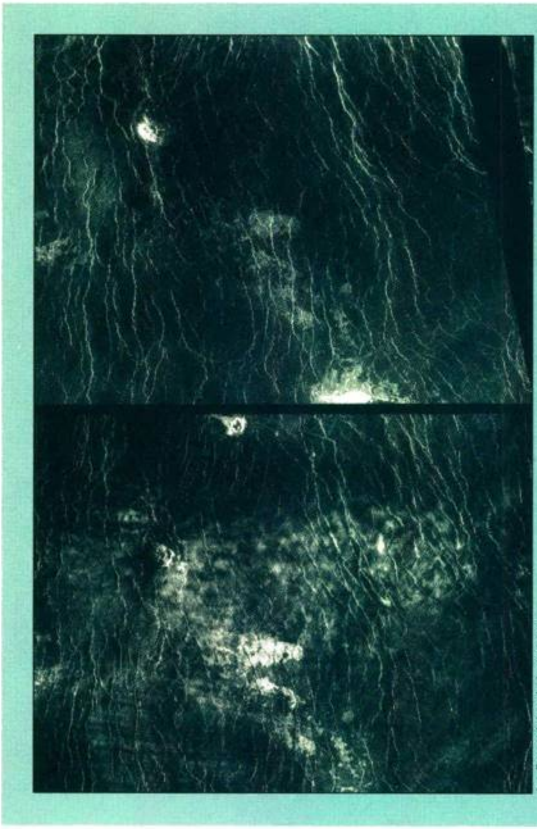

Jet Propulsion Laboratory

WIND SCULPTING ON VENUS could cause the difference between these two views of the same region taken eight months apart by the Magellan spacecraft. The bright patches and bands seen in the bottom image are either faceted rocks that face east (to the right) or regions of rough rock cleared of loose sand and dust during the eight-month period by surface winds. (The dark band visible in the top image is a missing data segment.) Astronomers plan for Magellan to take a third look at the region this month, which should resolve the nature of these bright features.

The new photos show many tiny distortions in the images of objects farther away than the cluster — a telltale sign of the presence of dark matter. The dark matter acts as a gravitational lens, bending the light from the more distant objects as predicted by Einstein's general theory of relativity. Among the unusual distortions are a giant arclike structure, which appears to be a distant source whose entire image is stretched out, and two individual images in near-perfect symmetry around the cluster's core, which appear to be two images of a single quasar split by the gravitational lens. By studying these and other similar distortions in the images of AC 114, the astronomers hope to map the distribution of dark matter throughout the cluster.

MOST LUMINOUS QUASAR OBSERVED SO FAR

As part of the Hamburg Survey of bright quasars, astronomers discovered HS 1946+7658, which is a bright, relatively distant quasar. The quasar's apparent magnitude of 15.6 doesn't indicate anything is unusual. But its absolute magnitude in the ultraviolet part of the spectrum is –31.1, making it the most luminous quasar known. Estimates of the quasar's radiation in other parts of the spectrum suggest that the quasar's total luminosity exceeds 10^{15} Suns. For comparison, the Milky Way Galaxy is 100,000 times fainter with a luminosity of just over 10^{10} Suns.

The observations by the group of nine astronomers led by H. J. Hagen of Germany's Hamburg Observatory indicate so far that the quasar is not variable. The quasar's brightness was the same in 1986 and in 1991. However, as the astronomers reported in the January (I) 1992 issue of *Astronomy and Astrophysics*, HS 1946+7658 is more than just another entry in a cosmic sideshow. The quasar should illuminate intergalactic helium clouds as its light passes through space. Determining the distances to such clouds may enable researchers to establish the era of galaxy formation.

THE NEWEST BEST STELLAR BLACK HOLE

The April issue of ASTRONOMY described why astronomers thought that A0620–00 was the best candidate for a stellar black hole. Shortly after that issue went to print, three astronomers reported periodic variations in the spectrum of the recurrent nova V404 in the constellation Cygnus. A G- or K-type star slightly cooler and less massive than the Sun causes the spectral variations as it orbits a dark companion every 6.47 days. As found from the orbit of the G- or K-star, the minimum mass for the dark companion is 6.26 times the mass of the Sun. The best estimates of the mass place it at 8 to 15.5 times the Sun's. The combination of high mass and X-ray emission leads the astronomers to believe the dark companion is a black hole. The February 13, 1992 issue of *Nature* contains Jorge Casares, Phil Charles, and Tim Naylor's description of their observations made with the William Herschel Telescope (Royal Greenwich Observatory) on La Palma Island in the Canaries.

STAR FORMATION IN LENTICULAR GALAXIES

Lens-shaped, or lenticular, galaxies fall between ellipticals and spirals in the amount of hydrogen gas they contain. As with elliptical galaxies, collisions with small spiral galaxies probably provide lenticulars — labeled by astronomers as S0-type galaxies — with their hydrogen gas. Emission by the galaxies in the red line of hydrogen and in the radio portion of the spectrum hints at ongoing or recent star formation, also suggesting recent collisions.

To study the distribution of gas through S0 galaxies — and thereby determine the origin of the gas — Lowell Tacconi of the Netherlands Foundation for Research in Astronomy and his colleagues measured carbon monoxide (CO) in 11 S0s. They found CO in 7 of the 11 galaxies. Their most extensive measurements were of NGC 1326, in which they detected a ring of molecular gas centered on the nucleus of the galaxy. The ring has a radius of roughly 3,000 light-years.

CO accompanies molecular hydrogen. Together these molecules form the basis of the clouds in which stars are born. As the astronomers report in the December (II) 1991 issue of *Astronomy and Astrophysics*, the CO measurements provide an estimate of how much molecular hydrogen is in an S0 galaxy. The seven galaxies in the survey each contain an amount of molecular hydrogen roughly equivalent to 100,000 times the mass of the Sun. This hydrogen mass is about what astronomers expect collision with a small galaxy would add to the galaxy.

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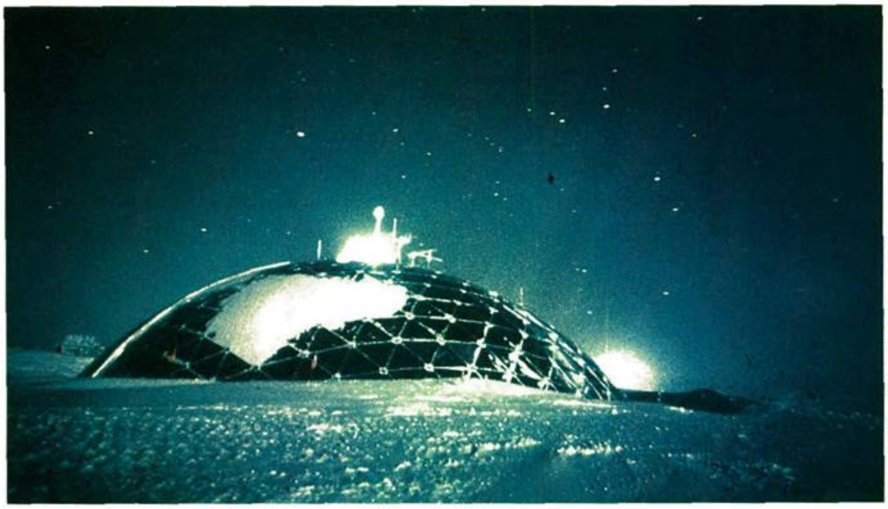

THE SOUTH POLE'S Scott-Amundsen research station will soon be home to several new telescopes.

John Kai Wing Chan, University of Leeds

ASTRONOMY FROM THE LAST PLACE ON EARTH

Researchers from the new Center for Astrophysical Research in Antarctica (CARA) are testing the view at the South Pole to learn how well they can see the stars. So far their tests are encouraging. The Center, headquartered at the University of Chicago's Yerkes Observatory, sent researchers to the bottom of the globe earlier this year during the Antarctic summer to monitor the transparency of the sky. "The data so far confirm that the sky conditions are excellent," said Al Harper, CARA Director.

Antarctica's skies are so clear that astronomers believe they can study galaxies and stars up to 100 times fainter than those visible at warmer latitudes. Harper said the polar sky will be especially suited to studies of radiation in the infrared and submillimeter parts of the spectrum because the cold air and cold telescopes won't emit as much radiation at these wavelengths as they do in warmer climates.

Also, the frigid polar air holds little of the water vapor that normally absorbs infrared light. Though visible light studies can be done only during the winter when skies are dark, infrared observations can continue through the perpetual daylight of Antarctic summer — though bright in visible light, the daytime sky appears dark when observed in the infrared.

CARA astronomers are planning three observing projects. One will search for structure in the early universe by studying the cosmic microwave background radiation. A second will observe infrared light from young galaxies and newly formed stars.

Researchers also hope to turn up evidence for brown dwarf stars, ones larger than planets but too small to trigger the thermonuclear reactions that power normal stars. The third program will focus on the stuff between the stars, the clouds of dust and gas out of which new stars are born.

Astronomers plan to head back south later this year and start their first observations of the background radiation in November. Instruments for the other projects should be operational by the start of the Antarctic summer in late 1993.

Amateur News

STAR PARTIES IN KANSAS AND TEXAS

The KAOS star party under control

The homecooked meals were fabulous and a bottomless pot of coffee kept everyone warm as temperatures fell to the freezing mark. Usually October is cool but pleasant in Kansas, but an Arctic cold front made for colder than normal nighttime temperatures. Still, the cold air brought clear skies and steady seeing conditions.

The occasion was the first Great Plains Star Party hosted by KAOS, the Kansas Astrophotographers and Observers Society. From October 4 to 6, 1991, about 75 people gathered at the club's Scopeville facility near Parker, Kansas, about 50 miles southwest of the bright lights of the Kansas City suburbs. There was no hint of sky glow from any city or town and the naked-eye visibility of objects such as the Andromeda Galaxy, the Beehive Cluster, and the Double Cluster made binocular and telescope viewing exceptional.

The organizers plan to limit attendance in the future so the quality of the hospitality stays high. To make your reservations for the 1992 KAOS Great Plains Star Party scheduled for August 27 to 30, contact Robert Nederman at 9200 Westbrooke Drive, Overland Park, KS 66214, (913) 888-7744. — *Larry Robinson*

The ultimate star party

A mile high and many miles from brightly lighted towns, Fort Davis, Texas, is a mecca for amateur and professional astronomers alike. Each April or May over 500 dedicated sky watchers gather at the Prude Ranch near Fort Davis for the annual Texas Star Party.

Some sky lovers who regularly attend the TSP each spring have for a long time wanted to experience the beauties of the winter skies from the mountains of Fort Davis. This desire led John Hudek to invite a group of us from around the country to gather last November for what was billed as "The Ultimate Texas Star Party."

And ultimate it was. The smallest scopes represented were 18-inch equatorial reflectors followed by a dozen 20-inch and no fewer than eight 25-inch Dobsonians. By strolling from scope to scope, you could hear even the experienced amateurs among us murmuring an occasional "Golly" or "You gotta see this!"

The first annual Ultimate Star Party proved to be a big success. About two dozen deep-sky fans enjoyed a week of cold but beautiful, clear nights among the mountains of Fort Davis below the domes of McDonald Observatory. This year, the Ultimate Star Party is tentatively set for the dark of the Moon in November. For more information contact John Hudek, c/o Galaxy Optics, P.O. Box 2045, Buena Vista, CO 81211, (719) 395-8242. — *Ed Boutwell*

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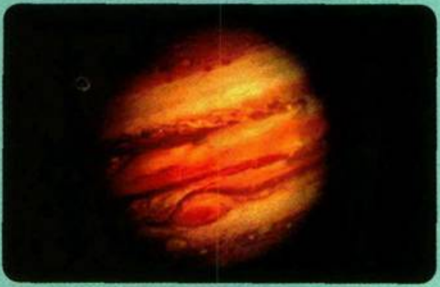

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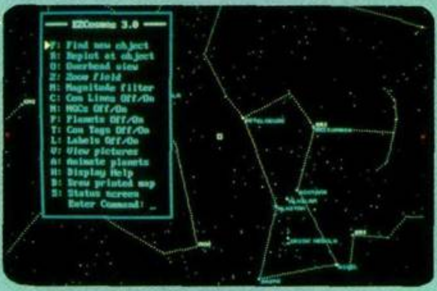

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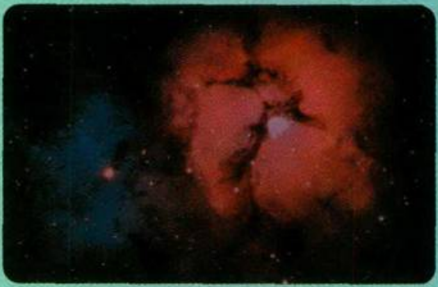

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ATLAS: MISSION TO EARTH, SUN, AND STARS

"This is what a space shuttle mission should be," reported mission scientist Marsha Torr during the March flight of Atlantis. "The data gathering is going just the way we had hoped it would." For nine days, 18 megabits of science data poured down every second from the shuttle's science package called ATLAS — the Atmospheric Laboratory for Applications and Science — the second component of NASA's Mission to Planet Earth program. (The Upper Atmosphere Research Satellite launched last September was the first.)

About half of ATLAS's 14 experiments were aimed down at Earth, studying the chemistry and winds of the upper layers of our planet's atmosphere. Four other instruments were aimed at the Sun. They made precise measurements of the critical "solar constant," the energy output of the Sun. Fluctuations of only 0.5 percent per century in the Sun's output could explain the swings over geologic times in Earth's climate from tropical to ice-age conditions, while smaller fluctuations such as 0.1 percent over the sunspot cycle could affect Earth's weather but in unknown ways.

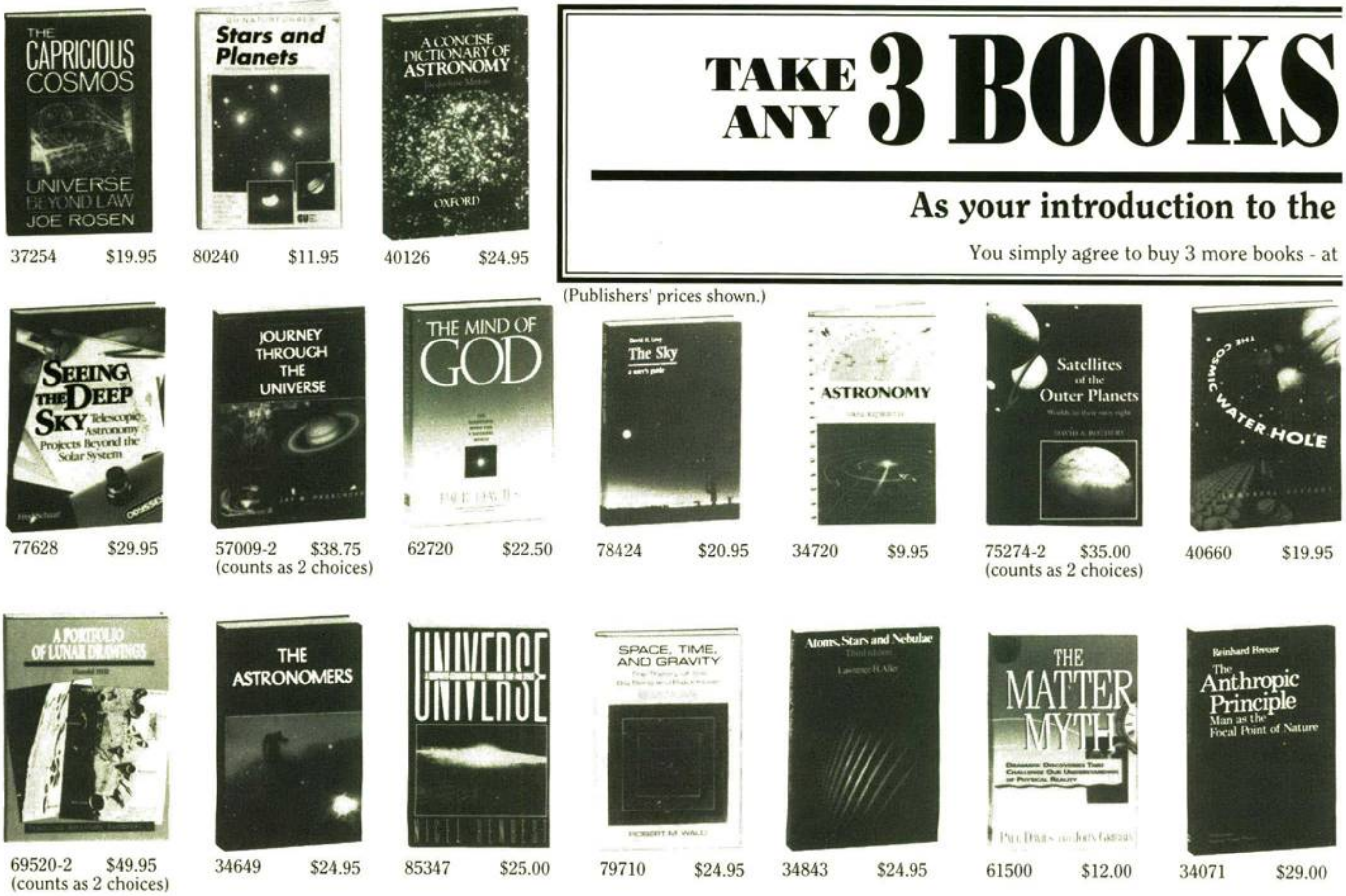
Project scientists were excited by how well the mission went. "ATLAS has amassed a database that is truly unique," said Torr. "Scientists will be referencing this database for at least two decades to come."

The ATLAS array also included an astronomical telescope, the Far Ultraviolet Space Telescope (FAUST), built in collaboration by the University of California at Berkeley and France's Laboratoire d'Astronomie Spatiale. FAUST was sensitive to the ultraviolet radiation emitted by very hot objects. Though ultraviolet telescopes have flown in space before, FAUST's unique characteristic is its wide 6° field of view, about the same as a pair of binoculars.

Unfortunately, technical problems with FAUST cut the planned 30 to 40 images to 20. "I'm disappointed we didn't get the rest," remarked principal investigator Stuart Bowyer. "You always want to get more, but it's hard not to be delighted with what we did get."

The images included ultraviolet views of the Large and Small Magellanic Clouds, a globular star cluster called NGC 6752, and clusters of galaxies in Coma Berenices, Virgo, and Telescopium. Over the next few months astronomers will examine FAUST's wide-angle images looking for clues to how small, hot stars called white dwarfs are distributed throughout the Milky Way, and how the dust between the stars varies from place to place in our Galaxy.

FAUST also observed a diffuse background glow of ultraviolet light, part of which is from very distant and unresolved galaxies. Measuring the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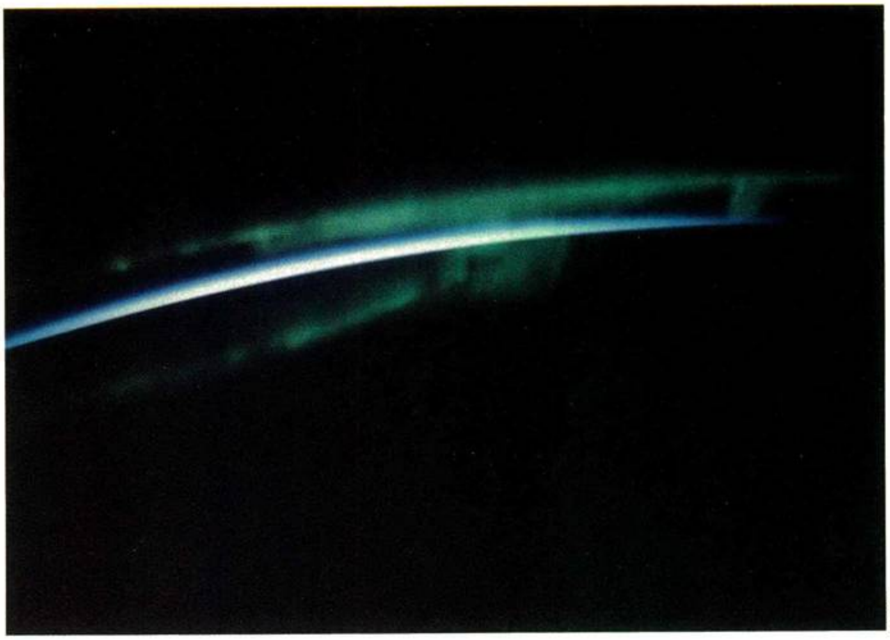
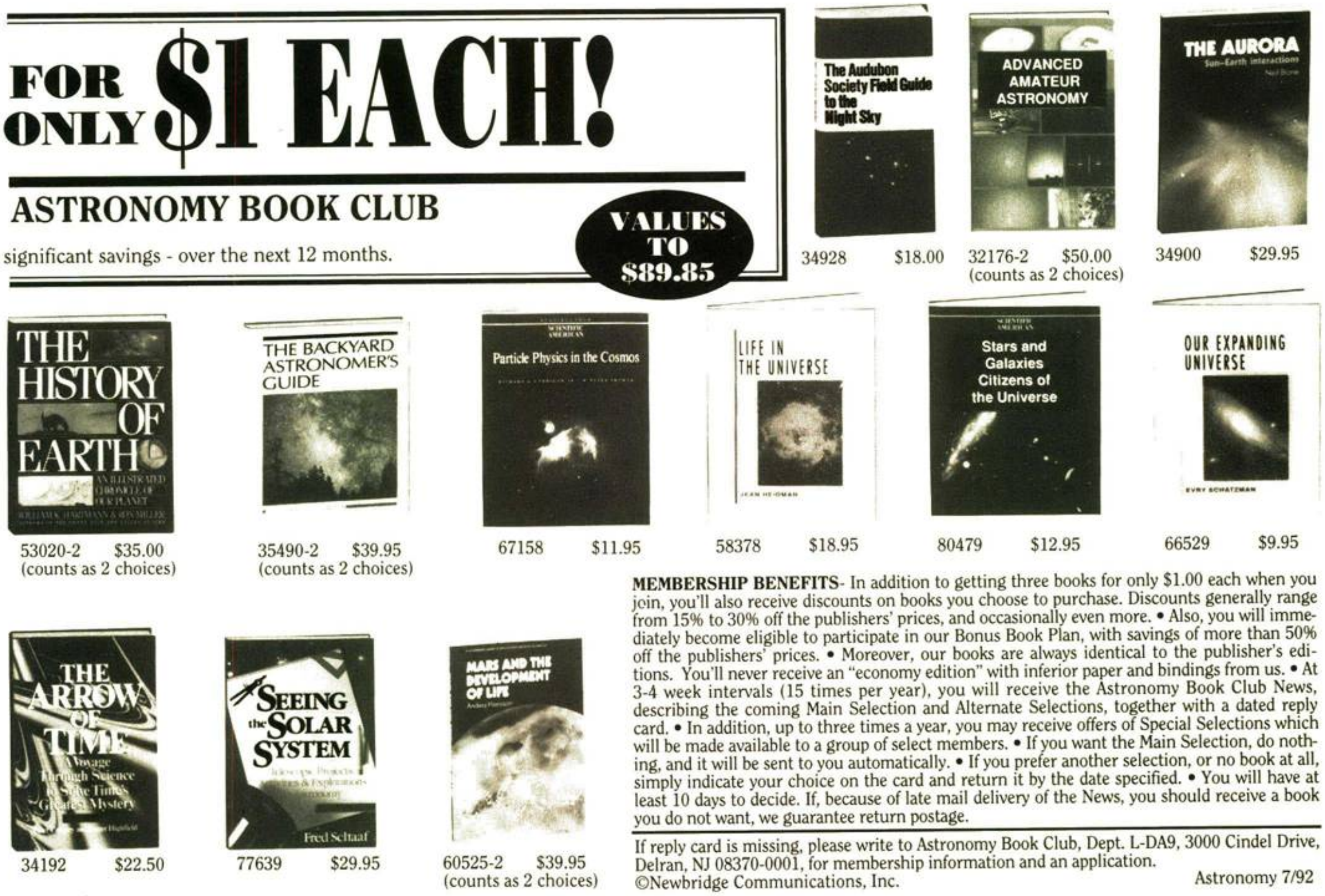
extent of the glow should give a measure of whether stars formed at a more prolific rate when galaxies were young. Patches of brightness in the ultraviolet background should also provide clues to the structure of the universe on the largest scales.

This is a rich harvest of information to cull from only 20 images, but compared with the meager amount of data obtained from the short-lived sounding rockets that ultraviolet astronomers have used in the past, FAUST's results are bountiful.

FAUST could fly again on a future shuttle mission but there is no funding yet to make that possible. However, the ATLAS pallet of Earth and solar science experiments will definitely fly again. ATLAS experiments are scheduled to fly into space up to eight more times over the next decade to create a picture of how fluctuations in the Sun's output affect Earth over a complete 11-year solar cycle. The next ATLAS mission is set for early 1993. ☐


NASA

A THIN BLUE LINE marks a layer of airglow in Earth's upper atmosphere. Above that lie curtains of green aurora in a scene captured by astronauts during the ATLAS shuttle mission in March.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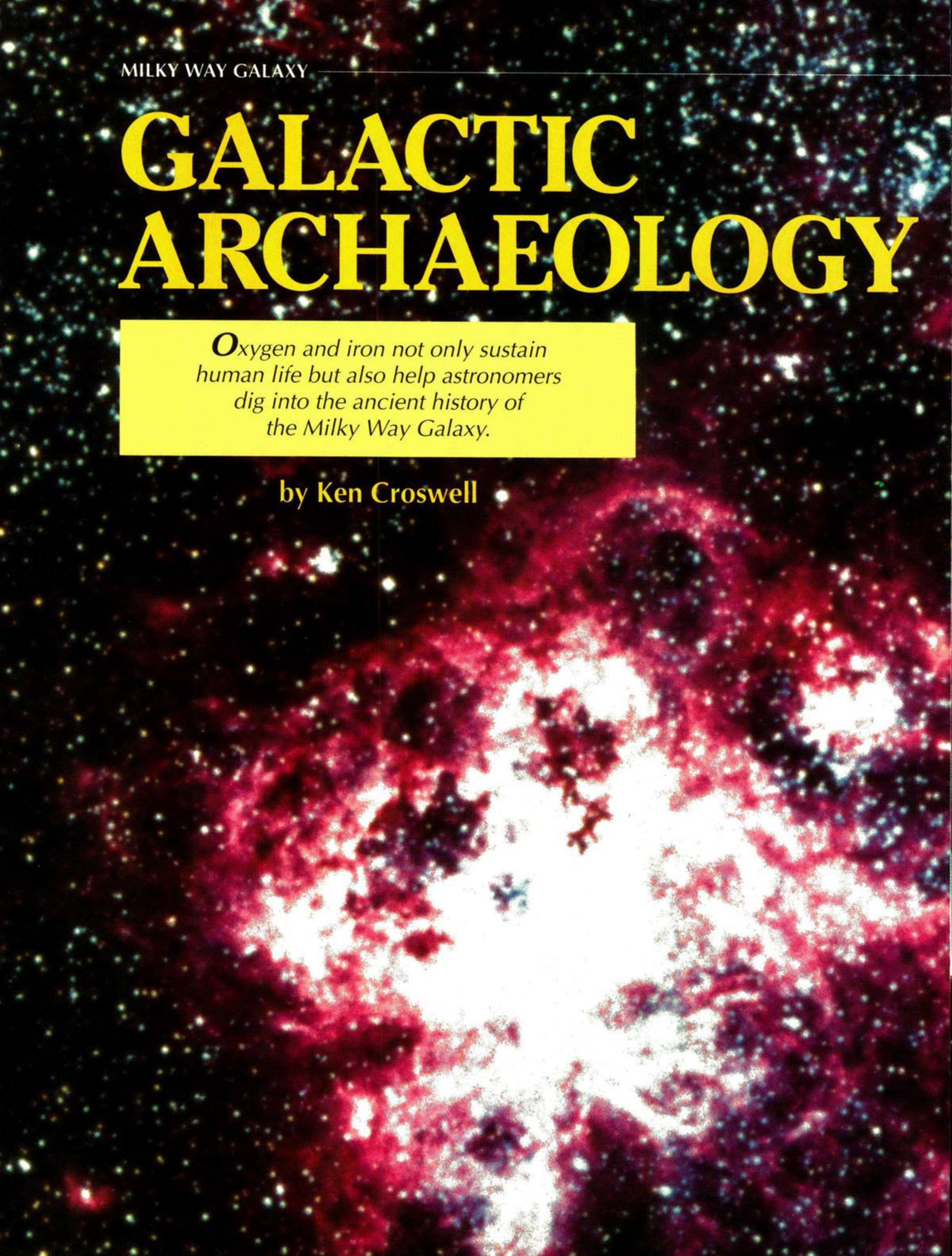
GALACTIC ARCHAEOLOGY

Oxygen and iron not only sustain human life but also help astronomers dig into the ancient history of the Milky Way Galaxy.

by Ken Croswell



A SUPERNOVA EXPLODES, throwing off debris that will enrich the interstellar gas and the stars that form from it.

European Southern Observatory

We'd be nowhere without oxygen and iron. Oxygen is in the air we breathe, the water we drink, and the rocks we stand on. Iron flows through our veins, supports our tallest buildings, and makes up our planet's hot core, which generates the magnetic field that protects us from high-energy particles emanating from the Sun.

Yet before the Galaxy formed, there was no oxygen or iron at all. At that time, stars like the Sun, planets like Earth, and living beings like us could not exist. The very first stars that did arise in our Galaxy likewise had no oxygen and iron. The most ancient stars that survive today formed shortly after this initial generation of stars and so consist almost entirely of hydrogen and helium, the two lightest elements.

Since then, the Galaxy's supply of oxygen, iron, and other heavy elements has grown. These metals — astronomers call all elements heavier than helium "metals" — were forged in stars and ejected. This material enriched the Galaxy, and later generations of stars and planets, including the Sun and Earth, acquired these heavy elements for themselves. Every oxygen atom and every iron atom in your blood came from a star.

We owe our existence to supernovae. They seeded the Galaxy with the heavy elements that make up our bodies.

The Galaxy's abundance of metals, or metallicity, has increased over the years. The oldest stars in the Galaxy, which formed when the Galaxy had few metals, have few metals themselves, whereas younger stars, like our Sun, have enough metals to give rise to Earth-like planets and life. The Sun, which is 4.6 billion years old, is 2 percent metals by weight, but a typical 10-billion-year-old star is just 0.02 percent metals, making its metallicity only one-hundredth the Sun's.

Astronomers have known about this progressive metal enrichment of our Galaxy for decades. More recently, though, they have discovered that different metals behave in different ways. The most interesting variation involves two of the most important metals: oxygen and iron.

Oxygen is the most abundant metal of all. But it is difficult to measure in stars because it is a relatively simple atom that creates few spectral lines. In contrast, iron is easy to measure because it is a complex atom that produces lots of spectral lines at optical wavelengths. So astronomers usually determine a star's metallicity by measuring its iron abundance.

After determining a star's iron abundance, astronomers traditionally assume that other metals behave exactly the same way — that is, if the star has one-half the Sun's iron abundance, it also has one-half the Sun's oxygen abundance, one-half the Sun's carbon abundance, and so on. For metal-rich stars like the Sun, this assumption is usually correct: the oxygen-to-iron ratio of metal-rich stars is the same as the Sun's.

For metal-poor stars, however, recent studies show this assumption is wrong, especially for oxygen. These old stars have oxygen-to-iron ratios that are higher than the Sun's. (In the Sun, oxygen nuclei outnumber iron nuclei by a factor of 20.) For example, a star with 1 percent the Sun's abundance of iron does *not* have 1 percent the Sun's abundance of oxygen. Instead, it may have 3 percent the Sun's abundance of oxygen, giving it an oxygen-to-iron ratio three times greater than the Sun's. The star still has less oxygen than the Sun, but it has several times more than one would expect based on its iron abundance.

Hunting for Oxygen

Because metal-poor stars formed shortly after the Galaxy itself did, their abundance patterns preserve a record of our Galaxy's distant past and hold key clues to what our Galaxy was like in its earliest years. The high oxygen-to-iron ratios in old stars can therefore tell us what was going on as the Galaxy was forming.

The first hint that the oxygen-to-iron ratio in metal-poor stars is higher than the Sun's came in the late 1960s. A few astronomers noted high oxygen-to-iron ratios in moderately metal-poor giant stars such as Arcturus and Gamma Leonis and even higher oxygen-to-iron ratios in more metal-deficient giants.

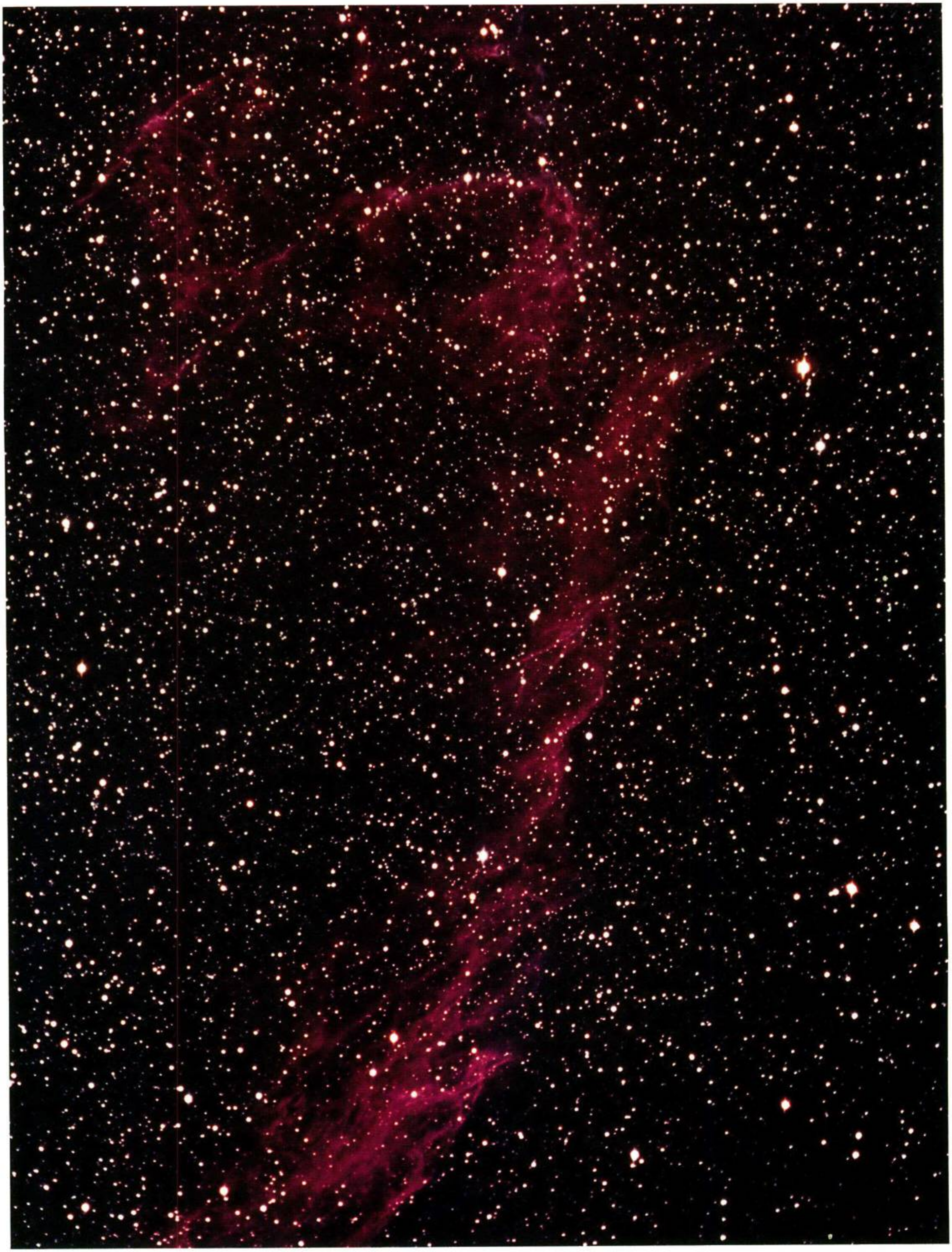
But giant stars are tricky: some giants fuse elements in shells around their cores, and mixing of the shells' gases with those of the outer layers may alter their surface compositions. The surface abundance of a giant may no longer be the same as the material from which the star formed.

Main-sequence stars are better. These stars generate energy by fusing hydrogen into helium at their cores, leaving their surface abundances of heavy elements untouched. Thus, the present surface composition of a main-sequence star should be the same as the composition of the Galaxy itself when the star formed, billions of years ago.

In the late 1970s, Christopher Sneden, David Lambert, and Rodney Whitaker investigated 13 main-sequence stars of various metallicities. They found that the oxygen-to-iron ratios of the metal-rich stars were the same as the Sun's but that the oxygen-to-iron ratios of the metal-poor stars were higher than the Sun's. Since then, astronomers have confirmed this work, finding that old, metal-poor stars have oxygen-to-iron ratios three or four times higher than the Sun's. The oxygen-to-iron ratio of the Milky Way has therefore decreased dramatically during the Galaxy's life.

This huge decrease in the oxygen-to-iron ratio means the relative production of oxygen and iron was radically different in the earliest years of our Galaxy than it is today. In the early years, when the metal-poor stars formed, the Galaxy was producing far more oxygen relative to iron than it is today. Or, to put it the other way, the Galaxy in the old days had not yet started to create much iron. The reason for the dramatic difference probably lies in the mechanism that ejects stellar matter into the interstellar medium from which later generations of stars form — supernova explosions. Of the two main varieties of

DEBRIS FROM AN EXPLODED STAR spreads out into the Galaxy, where it will one day join with other gas and dust to form a future generation of stars.



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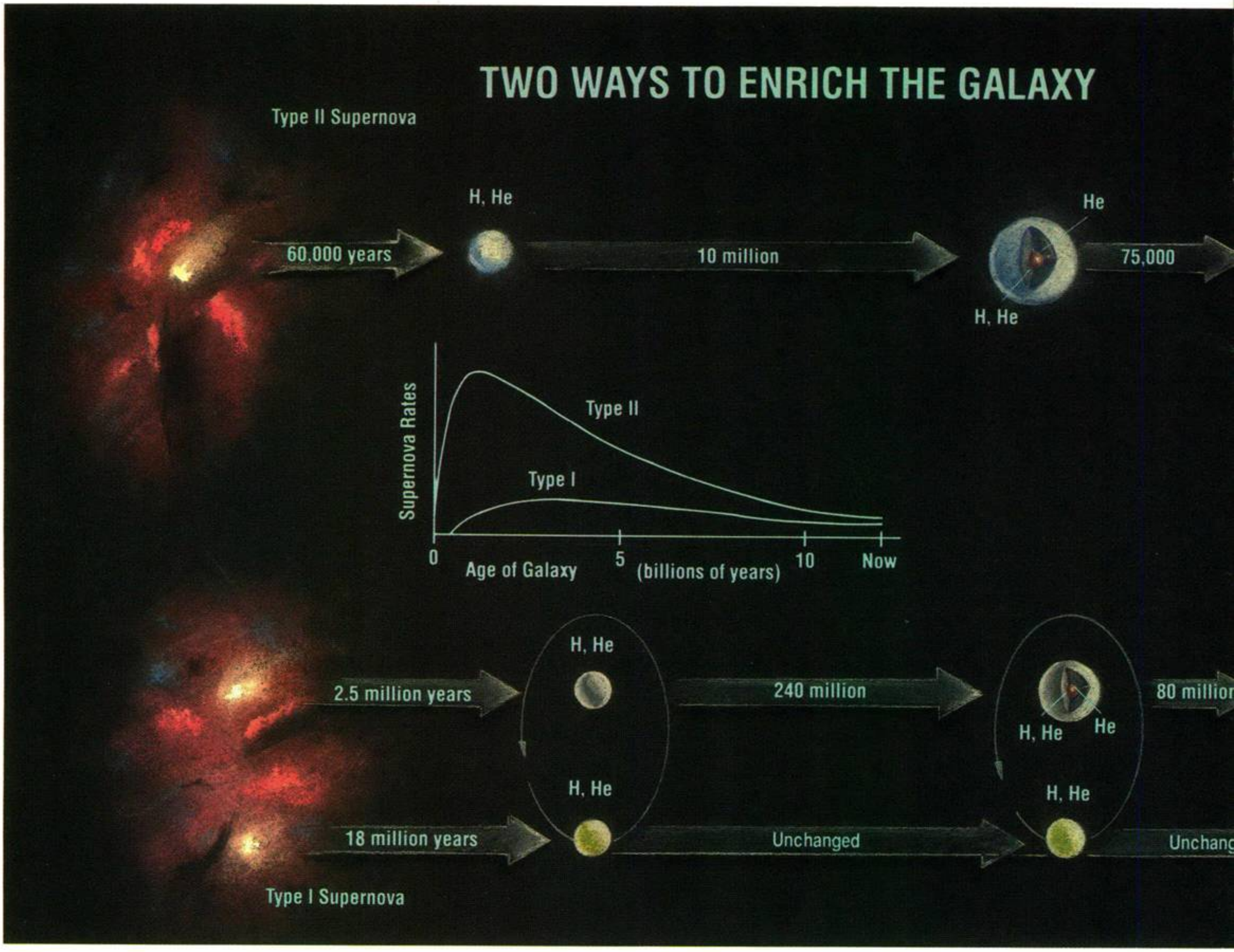


supernovae, one produces lots of oxygen, while the other produces lots of iron.

Explosive Clues

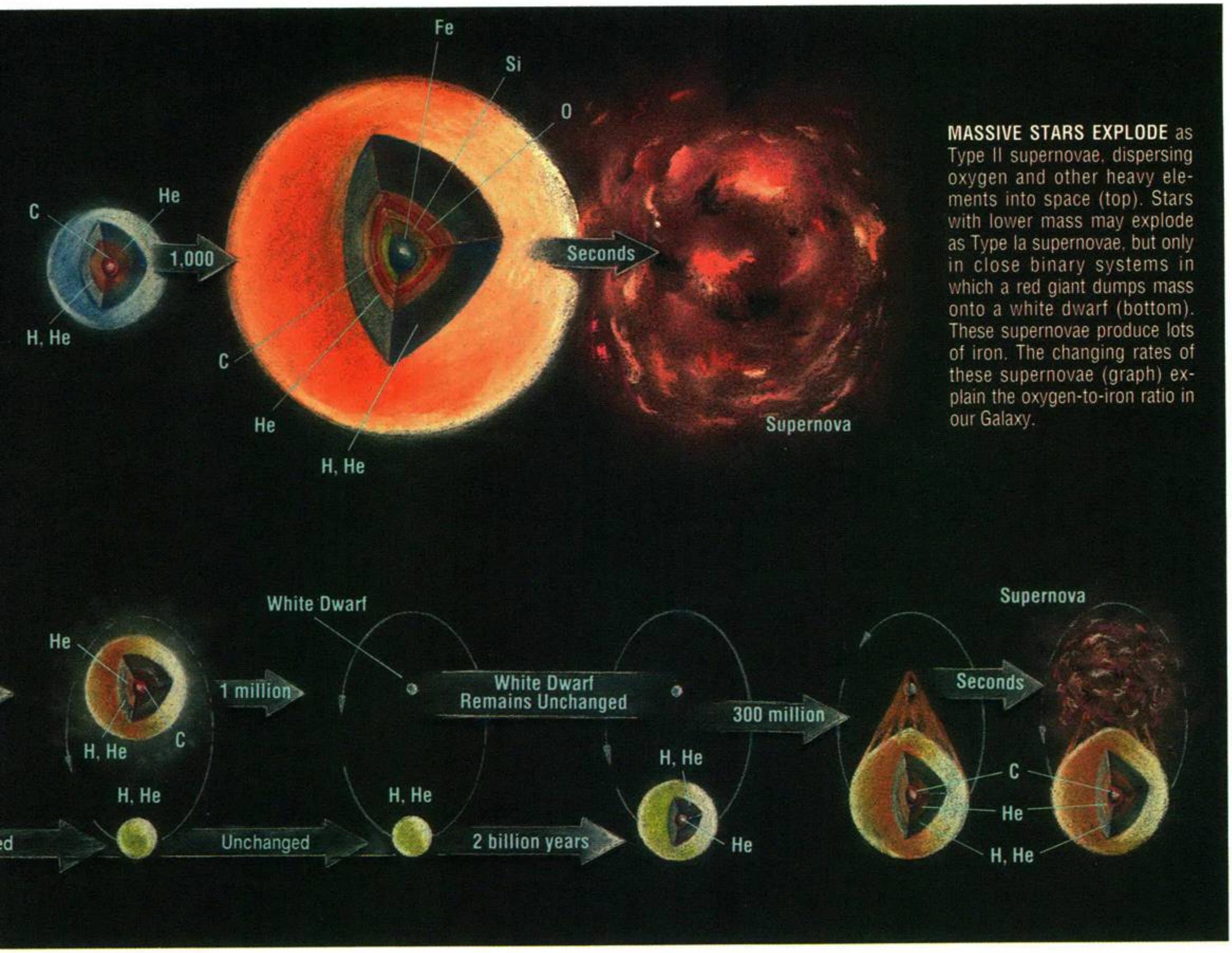
Supernovae are crucial to the Galaxy's chemical evolution, for supernovae have created many of the heavy elements now in the interstellar medium. To them we owe our existence, and to them we must look to discover why the Galaxy's oxygen-to-iron ratio was once higher than it is today.

Astronomers recognize four types of supernovae and designate them Type Ia, Type Ib, Type Ic, and Type II. The spectra of the various Type I supernovae all lack hydrogen, the most common element in the universe, whereas the Type II supernovae have plenty of hydrogen in their spectra. Despite this distinction, Type Ib and Ic supernovae arise from the same kind of star as Type II supernovae. Stars that explode as Type II supernovae have hydrogen envelopes, as the Sun does, whereas stars that explode as Type Ib and Ic supernovae have lost their hydrogen envelopes. This is why Type II supernovae show hydrogen in their spectra and Type Ib and Ic supernovae do not.

But these three types of supernovae — Ib, Ic, and II — all come from short-lived, high-mass stars, stars more massive than eight solar masses. High-mass stars are bright but rare: only one star in twenty thousand has a mass as great as eight solar masses. Yet because they are so luminous, many of these stars are quite famous. In fact, some of your best friends in the night sky are high-mass stars: Spica, Rigel, Deneb, Antares, and Betelgeuse probably all exceed eight solar masses and will someday explode as Type Ib, Ic, or II supernovae. Fortunately for us, these stars do not lie nearby. A nearby supernova would probably destroy all life on Earth.

Because a high-mass star is so bright, it must burn its fuel thousands of times faster than the Sun. The star begins its life by fusing hydrogen into helium the way our Sun does, but it soon graduates to heavier fuels, creating carbon, oxygen, neon, magnesium, silicon, and finally iron. Despite the many sources of energy, however, the star quickly runs out of fuel. The star's core collapses into a neutron star or black hole, generating a shock wave that initiates the supernova explosion. The total lifetime of a high-mass star is short, so almost as soon as the Galaxy formed, Type Ib, Ic, and II supernovae started exploding.

Although the nuclear reactions inside a high-mass star create both oxygen and iron, most of the iron stays behind when the star explodes. The reason:



MASSIVE STARS EXPLODE as Type II supernovae, dispersing oxygen and other heavy elements into space (top). Stars with lower mass may explode as Type Ia supernovae, but only in close binary systems in which a red giant dumps mass onto a white dwarf (bottom). These supernovae produce lots of iron. The changing rates of these supernovae (graph) explain the oxygen-to-iron ratio in our Galaxy.

ASTRONOMY: Phil Kirchmeier

before the star explodes, the oxygen and iron are in different places because they form at different times. Oxygen is the product of nuclear reactions that occur earlier in the life cycle of the star, so it resides in a shell outside the star's core. Iron, on the other hand, is the final product of the nuclear reactions and thus remains at the star's center. When the star explodes, the oxygen gets ejected into the Galaxy, while most of the iron gets sucked into the newly created neutron star or black hole.

Type Ib, Ic, and II supernovae therefore give off much oxygen but little iron. For example, the Type II supernova SN 1987A in the Large Magellanic Cloud ejected about 1.6 solar masses of oxygen but a mere 0.07 solar mass of iron.

In contrast, Type Ia supernovae give the Galaxy more iron than oxygen. But Type Ia supernovae take a while to get going. These supernovae arise from exploding white dwarfs. White dwarfs are small, dense stars; most have little hydrogen, so when they explode no hydrogen appears in their spectra. White dwarfs form from stars with masses less than eight times the Sun's — in other words, from exactly those stars that don't become Type Ib, Ic, or II supernovae. White dwarfs are very common, because most stars are less massive than eight solar masses. Ten percent of all stars in the Galaxy are white dwarfs.

But hardly any of these white dwarfs ever blow up. Only if a white dwarf reaches a mass of 1.4 Suns will it explode. This mass — the so-called Chandrasekhar limit — is the most a white dwarf can have. Anything more, and the star explodes. Before becoming a white dwarf, even a star as massive as eight Suns loses so much mass that the white dwarf it creates does not exceed the Chandrasekhar limit. In fact, the average white dwarf has only 0.6 solar mass, so most white dwarfs are safely below the limit and have nothing to fear.

If, however, a white dwarf is in a binary star system, and if its companion star gives mass to the white dwarf, the white dwarf may be in serious trouble. Little by little the white dwarf's mass grows from its starting value of 0.6 solar mass. If enough mass pours onto it, the white dwarf will reach 1.4 Suns — and the star will explode as a Type Ia supernova.

What makes the white dwarf explode? Most white dwarfs consist primarily of carbon and oxygen. When the mass reaches 1.4 Suns, the star's central pressure and temperature get so great that carbon nuclei fuse together, creating heavier elements and lots of energy. This energy raises the temperature further, which causes

Copyright Anglo-Australian Telescope Board more fusion, which creates still more energy, which raises the temperature still more, which causes still more fusion, and so on. A nuclear runaway occurs and the star explodes like a nuclear bomb, completely annihilating itself. Nothing remains. Instead, all the material returns to the Galaxy.

The most important element created during this deadly chain reaction is nickel-56. Nickel-56 is radioactive with a half-life of 6 days. It soon decays to cobalt-56, which is radioactive itself with a half-life of 78 days. Cobalt-56 then decays to iron-56, which is stable. The light of a Type Ia supernova comes not from the exploding star itself but from the energy of the radioactive decay of nickel to cobalt to iron. The final result: a Type Ia supernova gives the Galaxy about 0.5 solar mass of iron — an impressive achievement for a star of only 1.4 solar masses.

The nearest possible Type Ia supernova precursor is uncomfortably close. A mere 8.6 light-years away, the white dwarf Sirius B has a mass of 1.05 Suns, far above the average for white dwarfs. Sirius A, the white dwarf's more famous companion, is presently an A-type main-sequence star and is not losing much mass. But when Sirius A becomes a red giant, it will start to lose material, some of which will fall onto Sirius B. Little by little, Sirius B's mass may increase. Right now Sirius A has over two solar masses. If Sirius A loses half its mass and if Sirius B grabs most of that mass, Sirius B will exceed the Chandrasekhar limit and explode. All life within several dozen light-years of Sirius will probably perish.

Fortunately, this will take time, and by then Sirius will have drifted far enough away to spare us its wrath. This is the fundamental point about Type Ia supernovae: they take a long time before they explode. It takes time for a star to become a white dwarf, and it takes time for the white dwarf to receive enough mass to explode.

To put it another way: Type Ia supernovae have long fuses, whereas Type Ib, Ic, and II supernovae have short fuses. And Type Ia supernovae give the Galaxy iron, while Type Ib, Ic, and II supernovae give the Galaxy oxygen.

The Galaxy's Evolution

Now we can put the pieces together to study our Galaxy's evolution and, specifically, to explain why the oxygen-to-iron ratio in old, metal-poor stars is so much higher than it is in young, metal-rich stars.

Our Galaxy formed from hydrogen and helium gas that had essentially no metals. The first stars that arose in our Galaxy formed from this metal-poor gas. The high-mass stars quickly exploded as Type Ib, Ic, or II supernovae, blowing themselves up before the lower mass stars forming with them even reached the main sequence. These supernovae gave the Galaxy oxygen and other heavy elements, but little iron. The Galaxy's metallicity increased slightly, and the Galaxy's oxygen-to-iron ratio was high. Stars forming with material from these exploding stars acquired a low metallicity and a high oxygen-to-iron ratio.

Stars continued to form, and Type Ib, Ic, and II supernovae continued to explode. The stars now had somewhat higher metal abundances, though their metallicities were still far lower than the Sun's. The stars' oxygen-to-iron ratios remained high. As time went on, however, white dwarfs began to form from dying stars with masses below eight solar masses; though these white dwarfs started with masses below the Chandrasekhar limit, some were in binary systems, and some of these were slowly receiving mass from their partners. Meanwhile, Type Ib, Ic, and II supernovae kept increasing the Galaxy's metallicity.

A NEW GENERATION OF STARS FORMS from a cloud of interstellar gas and dust rich in heavy elements cast off in ancient supernova explosions.

Perhaps a few hundred million years later some of the white dwarfs in binary systems acquired so much mass that they exceeded the Chandrasekhar limit and exploded as Type Ia supernovae. Like the other supernovae, the Type Ia supernovae raised the Galaxy's metallicity. But the Type Ia supernovae produced a lot more iron than oxygen and lowered the Galaxy's oxygen-to-iron ratio. Thus, with both types of supernovae exploding, the Galaxy's overall abundance of heavy elements continued to increase but the oxygen-to-iron ratio started to fall. Stars continued to form from this material, with higher metallicities and lower oxygen-to-iron ratios.

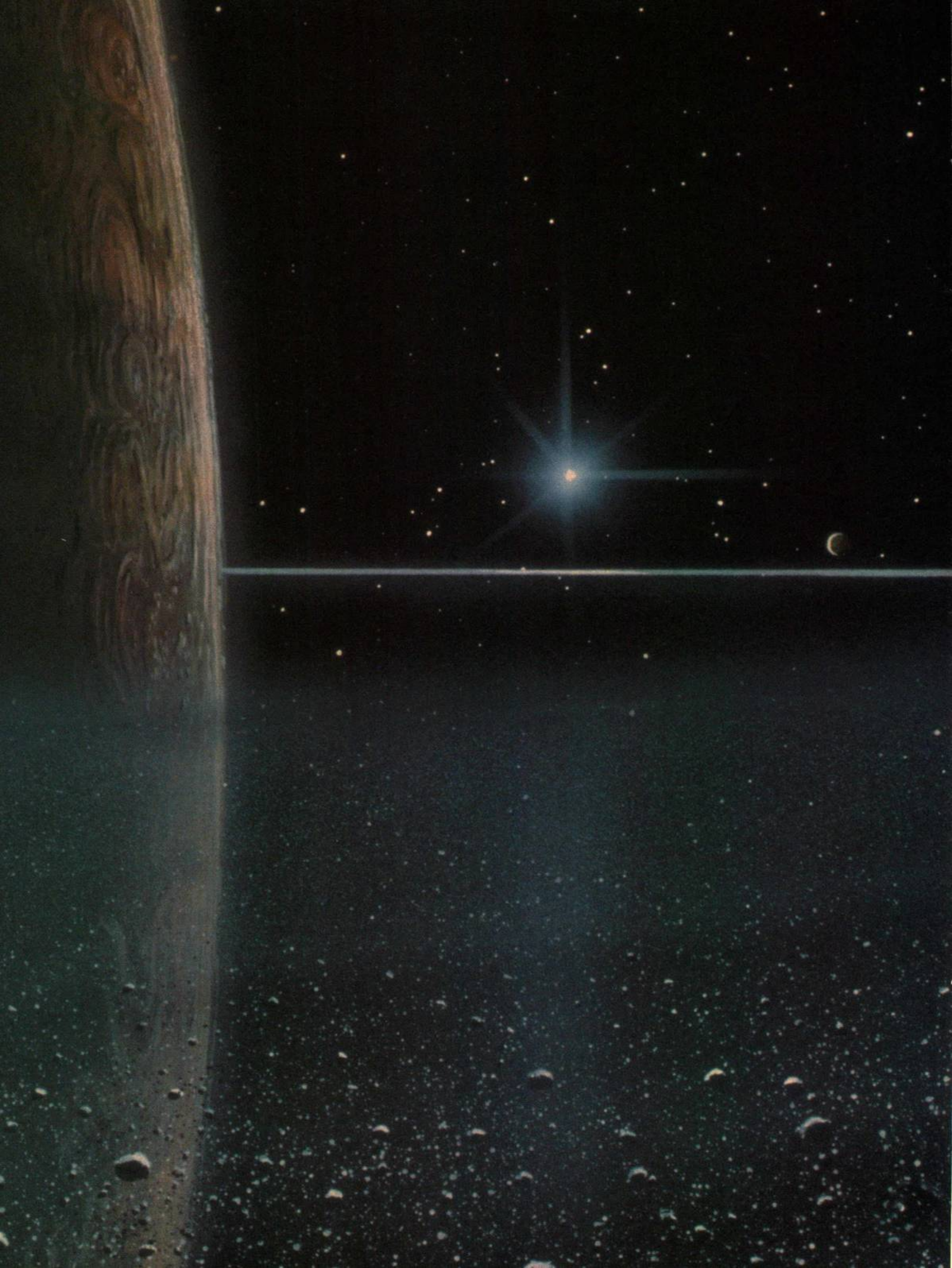
> ***T**ype Ia supernovae have long fuses and produce lots of iron; Type Ib, Ic, and II supernovae have short fuses and produce lots of oxygen.*

The process continues to this day. The Galaxy's metallicity is now so high that life can exist, and the oxygen-to-iron ratio is low, similar to the Sun's.

Of course, this model oversimplifies the Galaxy's actual evolution. Other events besides supernovae eject material into the Galaxy. Planetary nebulae, novae, and stellar winds all affect the Galaxy's evolution, as does any infall of material from outside the Galaxy. In addition, astronomers calculating what supernovae do usually base their computations on stars with solar metallicities because they want to model what currently observed supernovae should look like. However, the stars that exploded in the earliest years of our Galaxy were metal-poor.

Nonetheless, because they are the primary drivers of the Galaxy's chemical evolution, the two principal varieties of supernovae explain well the oxygen and iron in the Galaxy's stars. Through clever detective work and a knowledge of stellar evolution, we have deduced how the Galaxy acquired the heavy elements that have made our life possible, some ten billion years after the Galaxy's first stars set the whole process into motion. ☐

Ken Croswell received his Ph.D. in astronomy from Harvard University for his study of distant, metal-poor stars in the Milky Way Galaxy. He writes frequently for ASTRONOMY, New Scientist, *and other magazines. His last article for ASTRONOMY was "To the Edge: Missions to Pluto and Neptune" in the May issue.*



DESPERATELY SEEKING J·U·P·I·T·E·R·S

Planets should be a natural by-product of the formation of single stars. But in spite of intensive searching, astronomers have yet to find planets around Sun-like stars.

by David Bruning

The discovery of the first planets outside the solar system surprised most astronomers. It wasn't because planets had finally been detected after decades of searching. It was because the planets orbit an unlikely star — a pulsar called PSR 1257+12 — in the constellation Scutum. They expected to find planets orbiting a star much like the Sun, instead of a star near the end of its life cycle. In the case of PSR 1257+12, the star's violent death throes as it became a pulsar should have destroyed any planets.

Astronomers now believe that the observed planets formed after a supernova explosion created PSR 1257+12 from the more massive star in a binary system. (See "Lost and Found: Pulsar Planets" in the June 1992 issue.) The intense radiation from the pulsar evaporated its companion, creating a disk of gas around the pulsar from which the planets formed. Because the planets formed long after the stars, researchers call them second-generation planets.

So in spite of their initial surprise, researchers feel confident that they understand how the pulsar planets came into existence. But a fundamental mystery still plagues astronomers. They believe first-generation planets orbiting Sun-like stars should be plentiful, forming from the rich gas and dust disks left behind during the birth of the parent star. Yet numerous search teams continue to come up empty-handed. Despite several decades of looking, no confirmed detections of first-generation planets exist, although several intriguing planetary candidates have surfaced.

Until recently, the best candidate for a stellar system containing a low-mass companion was a star known by its catalog number, HD 114762. HD 114762 is a 7th-magnitude star that is slightly hotter than our Sun and located about 90 light-years away in the constellation Coma Berenices. David Latham of the Harvard-Smithsonian Center for Astrophysics and his colleagues studied HD 114762 as one of over 1,500 stars in their survey of stellar motions. They found that the star appears to move periodically toward and away from us every 84 days. The velocity of this radial motion can be measured with a spectrometer. As the star moves toward us, the dark lines in its spectrum shift toward the blue end of the spectrum. Later in the orbit when the star moves away from us, the spectral lines shift toward the red. The amount of shifting to the blue and red allows researchers to determine the star's radial velocity.

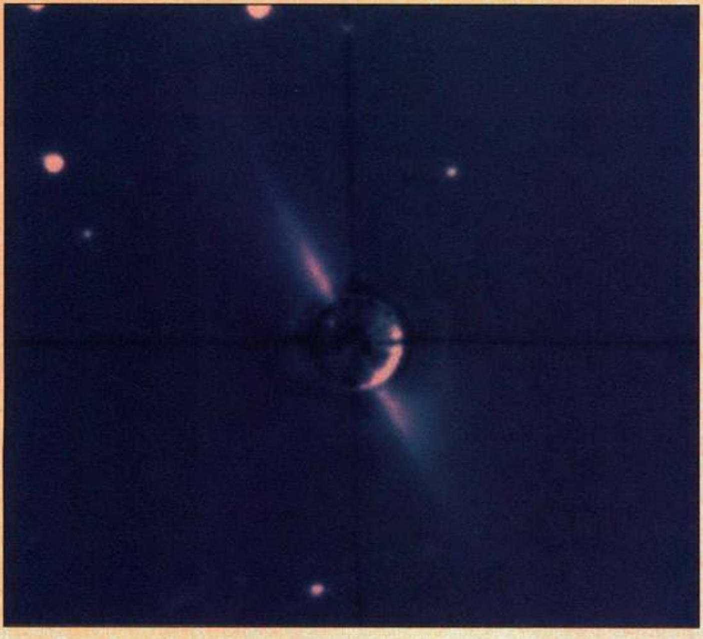
The simplest explanation for a periodic variation in the star's radial velocity is that a companion tugs on the star. The companion's gravity makes the star orbit about the common center of mass between the two objects, just as Jupiter's gravity makes the Sun orbit their common center of mass. (If you could put the two objects on the ends of a stick, the center of mass is the point where the stick balances on your fingertip.) Jupiter's gravity, for example, induces a 13-meter-per-second solar motion, while Saturn's produces a 3 m/s motion and Uranus' only 0.3 m/s. Earth causes the Sun to orbit at 9 centimeters per second, but Jupiter at Earth's distance from the Sun would create a 28 m/s motion. So by analyzing a star's radial-velocity variations, astronomers can determine the star's orbit about the center of mass and find the mass of the companion.

The analysis of HD 114762's orbit by Latham and his team indicated that the companion had a mass of at least 11 times Jupiter's. But because the unknown tilt of the orbit as seen from Earth affects the mass determination, the companion could be as massive as 80 Jupiters, which is the minimum mass needed for an object to burn hydrogen at its core and thus become a star. The astronomers calculated that there is only a 1 percent chance that the orbit could be tilted nearly face-on. Thus they felt that the companion was not a small star but instead a large planetlike body.

Recent high precision measurements by William Cochran and Artie Hatzes of the University of Texas confirm the companion's orbit (see page 39). But other measurements by Cochran and Hatzes and by Alan Hale of New Mexico State University indicate that the system may in fact be viewed nearly face-on. The astronomers assume that the companion's orbit lies in the same plane as the star's equator, just as the orbits of the planets of our solar system lie nearly in the same plane as the Sun's equator. By measuring the star's apparent rotational speed and comparing it with that of stars of similar temperature, they estimate that the companion's orbit may be tilted by as little as 8 degrees. The small tilt implies that the companion's

Illustration by Ron Miller

AS A JUPITER-LIKE PLANET ORBITS its parent star, it betrays its presence by reflecting starlight, re-emitting energy from the star, and causing a slight motion of the star as it moves through space.



NASA, courtesy Brad Smith and Richard Terrile

Indirect Evidence for Planets

Direct searches for planets around other stars have yet to reveal any promising candidates. But there is indirect evidence that planetary systems may be out there. Many young stars have dust disks surrounding them. These disks appear similar to the disk from which astronomers believe our solar system formed.

As many as 60 percent of young stars show evidence of a dust disk, including HL Tauri, FU Orionis, 51 Ophiuchi, DG Tauri, and L1551-IRS5. These early disks have a mass as large as 0.01 times that of the Sun. Vega's dust disk is twice as large as our solar system and contains particles only 1 millimeter in size. Slightly older stars, such as Beta Pictoris (shown in the photo above), have more tenuous disks of less than one-millionth of the Sun's mass.

Beta Pictoris lies 56 light-years away from the Sun. The diameter of its dust disk is at least 10 times larger than our solar system. A smaller gas disk lies inside the dust disk with a radius similar to the size of Mars' orbit about the Sun. At the same time as lumpy material appears to fall into the star, Beta Pictoris itself appears to eject gas. Observations of these inflows and outflows of material may help astronomers learn how the solar system cleared itself of material after the planets formed.

Dust disks evolve on a time scale of just a few million years. By about 10 million years, the disks have largely dissipated. So planet building must take place in this 10-million-year period. Spectroscopic studies also reveal the composition of the disks. HL Tauri has water-ice grains in its disk, which are perhaps similar in nature to our cometary matter.

It is not clear whether all disks eventually produce planets. FU Orionis stars exhibit strong flares that may push the disk away, preventing the production of planets. But irregularities in the disk around Beta Pictoris may be due to the motions of planetlike bodies.

mass is near 80 Jupiters, making it a small star and not a planet. With HD 114762 apparently out of the running, astronomers have refocused their planetary search efforts to other stars.

Looking for Planets

The next best case for a possible planetary companion to a star is Gamma Cephei. Bruce Campbell, Gordon Walker, and their colleagues detected 25 m/s variations in the radial velocity of this star. The variations occurred with a period of 2.7 years, which implies that a companion of 2 Jupiter masses may orbit the star. Of 16 stars in their survey, 7 showed similar variations at a level of 20 m/s. These variations could be produced by objects of 1 to 9 Jupiter masses in orbits that have periods of less than 50 years. Even though the precision of their measurements was about 10 m/s, it isn't clear that the variations were caused by planets.

Although astronomers require additional observations to determine the source of errors in their measurements, systematic errors seem to limit most radial velocity searches to about 10 or 20 m/s over short periods of observation. The cause may not be in the instruments but in the stars themselves. Measurements of the Sun show that its surface pulsates, creating radial velocity variations of up to 10 m/s. Also, hot, rising gas in the Sun's atmosphere cools as it emits energy, only to sink once again below the Sun's visible surface. The rising and falling of the gas, called convection, produces spectral-line shifts which astronomers observe as radial velocity variations. The combination of pulsation and convection produces radial velocity variations of 10 to 20 m/s in the Sun.

These natural velocity variations are about the same size as the variations expected from planets, so at first glance planetary detection seems impossible. But in this case, the impossible only takes a little longer. Most of a star's velocity variation occurs randomly. So a program that observes stars regularly for many years can differentiate between the irregular variations of a star's surface velocities and the periodic motion induced by an orbiting planet.

Several such observing programs are under way. William Cochran and Artie Hatzes, Geoff Marcy (San Francisco State University) and Paul Butler (University of Maryland), Robert McMillan and his colleagues at the University of Arizona, and Gordon Walker (University of British Columbia) and his team have spent years developing observing techniques capable of measuring radial velocities with unprecedented precision. Each group has concentrated on stars of different age or temperature, complementing the objects observed by other groups. But they also observe some of the same stars in order to check one another's results.

To provide the high precision needed for planetary searches, some of the groups use a gas absorption cell placed before the entrance to the spectrometer. The cell superposes dark lines on the star's spectrum to provide a standard velocity reference with which to compare the stars' velocities. Astronomers also need the reference lines so they can subtract the effects of Earth's motion on the stars' velocities.

The Arizona group uses an optical device called a Fabry-Perot interferometer in place of the gas absorption cell to superpose a velocity reference upon the star's spectrum. The use of entirely different techniques to measure radial velocity enables the astronomers to determine whether any error results from a particular observational technique.

So far Marcy and his collaborators find a long-term accuracy of 20 to 25 m/s. Planned improvement in their technique should cut this error in half, enabling the detection of planets of several Jupiter masses in Jupiter-like orbits about Sun-like stars or the easy detection of Jupiter-sized bodies orbiting at Earth's distance. But so far the group has detected no planets. McMillan's group has observed for about 7 years, obtaining a long-term error of about 3 m/s. Although variations appear in the radial velocities of several stars owing to stellar pulsation or low-mass stellar companions, no planetary companions have been detected.

Other Searches

Planetary searches also use other techniques. Instead of measuring a star's velocity as it orbits its system's center of mass, astronomers look for the displacement of a star from the center of mass. The wiggling of the star back and forth is a small effect, right at the present limit of stellar position measurements. Barnard's star, a cool, faint star located nearby in the constellation Ophiuchus, was once thought to have two planetary companions because it showed positional, or astrometric, variations. Astronomers now believe the variations were caused by the telescope, thus evaporating hopes for the existence of planets around this star.

Another search technique looks for starlight reflected by the planet. Two problems are inherent in this technique. First, Jupiter appears roughly one billion times, or 22 magnitudes, fainter than the Sun. Even for nearby stars, Jupiter-like planets would be near the limit of detectability. Second, planets in Jupiter-like orbits would appear close to the star and would be lost in the star's glare. A planet orbiting a nearby star typically would appear less than 1 arcsecond away from the star, making such a search impossible from Earth.

After astronauts install Hubble's corrective optics in 1994, the Space Telescope will search for the light from planets. High above the distortion caused by Earth's atmosphere, the Space Telescope with its 0.1-arcsecond resolution could detect Jupiter-like planets' orbiting nearby stars.

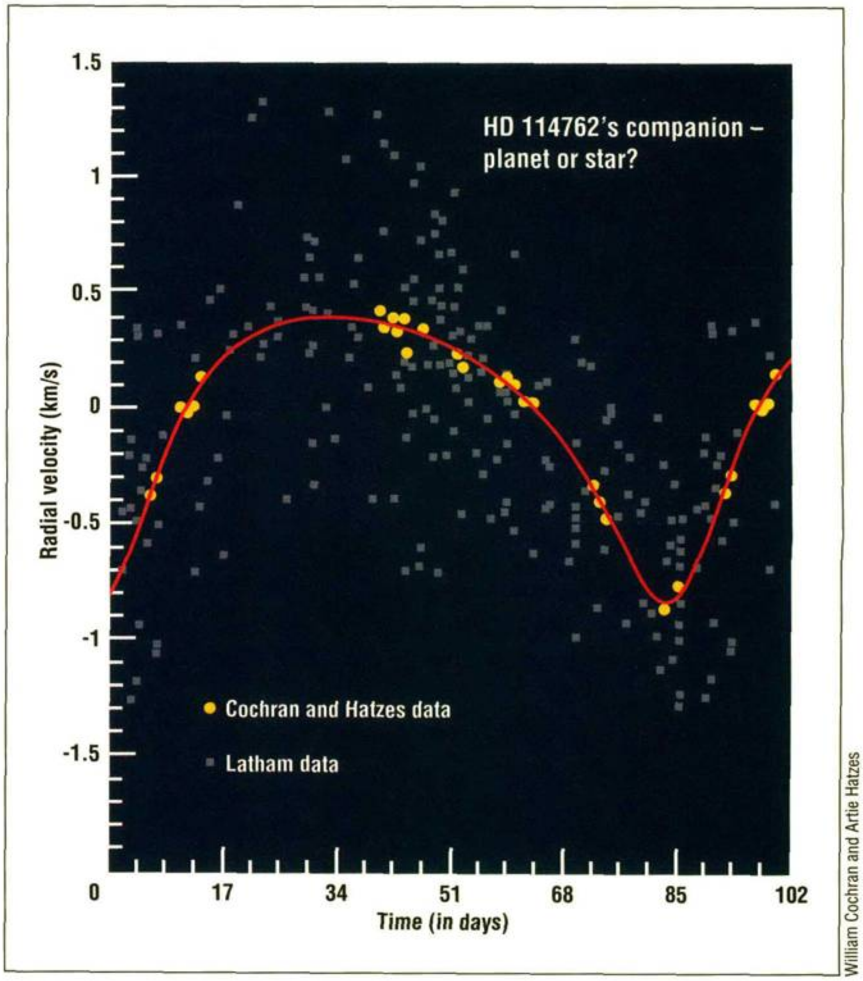
Astronomers can also look for the 0.01 percent dip in the brightness of a star as an Earth-sized planet crosses, or transits, the star's disk as seen from Earth. By chance, one planetary system out of a hundred would appear edge-on, enabling researchers to see planetary transits. So an aggressive observing program that looks at 1,000 stars per year as proposed by William Borucki of the NASA Ames Research Center might detect as many as 10 planetary systems.

But so far no planets have been detected with any observing technique. Perhaps the lack of planetary detections is only a result of the short period the groups have been observing. A star with a Saturn-like body orbiting it would require 20 or 30 years of observations before its radial-velocity variations, astrometric variations, or brightness variations due to a transit would be detected. On the other hand, perhaps the lack of detections isn't a result of what isn't seen but of what isn't there.

Forming Planets

Present ideas about star formation suggest that 60 to 80 percent of solarlike stars form in binary or multiple star systems. The remaining 20 to 40 percent are single stars. A star forms as a giant cloud, or nebula, of gas and dust contracts, heating the inner portion of the star until nuclear fires ignite. Some of the gas and dust left behind by the contracting nebula produces a disk of material that surrounds the star. Collisions between dust particles slowly build larger and larger particles, eventually forming planet-sized bodies.

Indirect evidence, such as the excess of infrared emission from dust disks observed around some single stars such as Vega and Beta Pictoris (see Indirect Evidence for Planets opposite), supports this accretion model of planet formation. Because the formation of nearly all single Sun-like stars produces dust disks, an



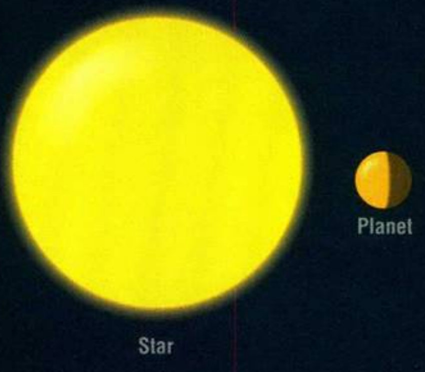
William Cochran and Artie Hatzes

NEW HIGH-PRECISION MEASUREMENTS confirm the back-and-forth motion of the star HD 114762. But other data suggest the companion is a low-mass star, not a planet.

HOW TO FIND PLANETS

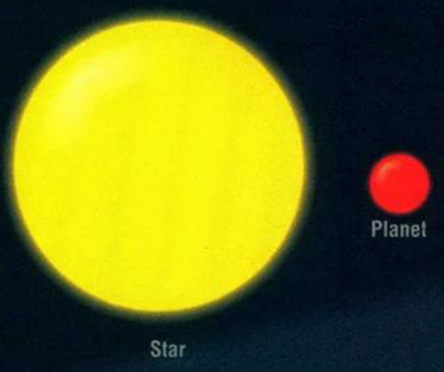
Direct Methods

Visible imaging



Direct viewing of starlight reflected by a planet is at the limit of the ability of orbiting telescopes. A Jupiter-like planet would appear 1 billion times fainter than a Sun-like parent star, making its detection difficult. For a star over 15 light-years away, a planet orbiting in a Jupiter-like orbit would appear less than 1 arcsecond from the star.

Infrared imaging



Radiation from the parent star heats planets to temperatures that range between 50 and 700 K. The planets re-emit this heat in the infrared. Imaging of the region around Sun-like stars may reveal the faint glow of Jupiter-like planets. But like the light reflected from planets, the infrared glow is faint and difficult to see.

SEARCHES FOR PLANETS AROUND OTHER STARS look for light coming from the planet or for motions of the parent star caused by the planet's gravity.

abundance of planets should exist around these stars. Perhaps the lack of planetary detections so far indicates that making Jupiter-sized bodies is more difficult than star and planet formation models suggest.

Some computer simulations indicate that high- and low-density regions created in the dust disk by the accreting bodies may limit the upper size of the bodies that can form. The upper limit may in fact be the size of Jupiter. So searches for more massive bodies may prove fruitless. Present models of planetary formation also hint that the formation of a planetary system may require a Jupiter-sized body. But some evidence suggests that Jupiter-sized bodies are hard to build. The lifetime of stars twice as massive as the Sun isn't long enough to permit the completion of planets. For dust disks around stars like the Sun, simple accretion to a Jupiter-sized mass takes longer than the disk's lifetime. So to build the planet's core in the 10-million-year period before the disk dissipates, the core accretion must accumulate material faster as time wears on. Toward the end of the core accretion process, material must accumulate so fast that astronomers call it runaway accretion.

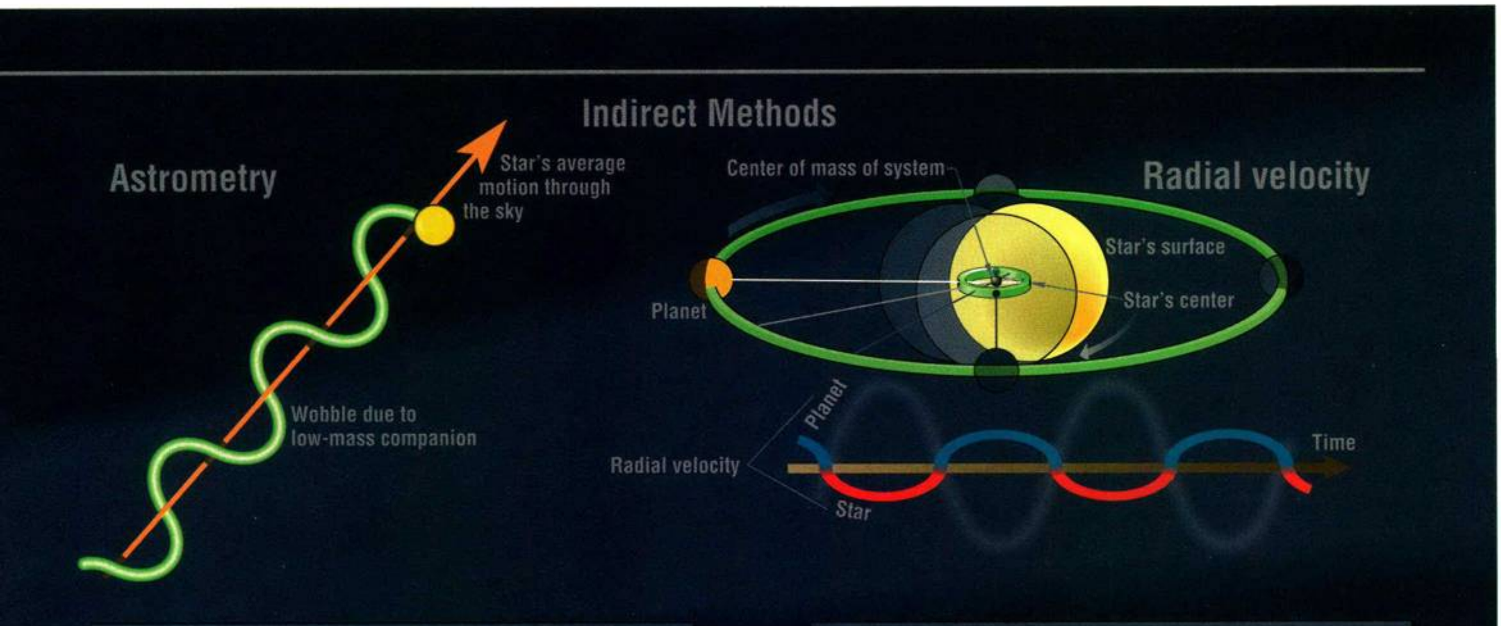
So perhaps there are many causes for the lack of planetary detections: smaller bodies than astronomers can presently detect, fewer planetary systems with Jupiter-sized bodies, and fewer planetary systems around solarlike stars. Another clue that building small objects isn't easy comes from the brown dwarfs, which are failed stars — gaseous bodies with insufficient mass to ignite or sustain nuclear reactions in their cores. In size, brown dwarfs fit between the smallest stars and planets. Astronomers differentiate between brown dwarfs and planets on the basis of how they formed. Brown dwarfs form from the contraction of a gas cloud and planets form from the accretion of gas and dust around a star. By this definition, Jupiter is not a failed star, as is often stated in astronomy textbooks. But planets and brown dwarfs do have one thing in common — astronomers have no sure detections of either.

Missing Brown Dwarfs

Star counts in our Galaxy show that low-mass stars are far more numerous than high-mass stars. Stars like the Sun are more numerous than hot, massive stars such as Vega, and cool stars such as Proxima Centauri (Alpha Centauri C) are more numerous than the Sun. The numbers of stars increase all of the way down to the lowest mass stars. The large number of low-mass stars reflects the greater chance of a gas cloud's fragmenting into smaller clouds than its forming a massive star.

The lowest mass stars have a mass only 8 percent of the Sun's (80 Jupiters). Below this mass, the few, if any, nuclear fires inside the core aren't sufficient to prevent the body from contracting further. But if stars increase in number down to the limit of 0.08 solar mass, the formation process should create at least as many low-mass brown dwarfs. And of the binary systems containing a cool star as the more massive star, about 15 percent should include a brown dwarf.

Radial-velocity searches for brown dwarfs around other stars have not detected any brown dwarf candidates. The searches extend down to 0.02 solar mass for objects with periods of 30 years or less. They also exclude objects of 0.01 solar mass with periods of



A planet's gravity tugs on its parent star, making the star's path through the sky appear to wobble. A Jupiter-like planet orbiting a Sun-like star makes the star move along an orbit the size of the star. From 10 light-years away, the star would appear to wobble back and forth by 0.0015 arcsecond. Astronomers currently can detect a wobble of less than 0.004 arcsecond.

As a planet orbits its parent star, the planet's gravity tugs on the star, causing it to move first toward us and then away from us. The changing velocity makes the dark lines in the star's spectrum shift first to the blue and then to the red. Current detection limits are about 10 meters per second, which is comparable to the Sun's velocity caused by Jupiter.

ASTRONOMY: Steven Davis

less than 10 years. A possible 0.08-solar-mass object orbits Gliese 623, but its mass suggests it's a low-mass star and not a brown dwarf.

Searches with infrared detectors (brown dwarfs emit mostly in the infrared part of the spectrum) also have failed to detect brown dwarfs. Perennially, several brown dwarf candidates surface, but as astronomers more accurately determine the orbit of the object or more precisely measure the object's brightness, the candidates either increase in mass to become low-mass stars or disappear entirely, having been only an artifact in the data. So stars like LHS 2924, VB 8B, and VB 10 have come and gone on the rolls of brown dwarf candidates.

One candidate that hasn't yet disappeared is GD 165B, a companion to a white dwarf, but its mass is uncertain. It might be near the 0.08-solar-mass dividing point, but so far it remains one of the best candidates.

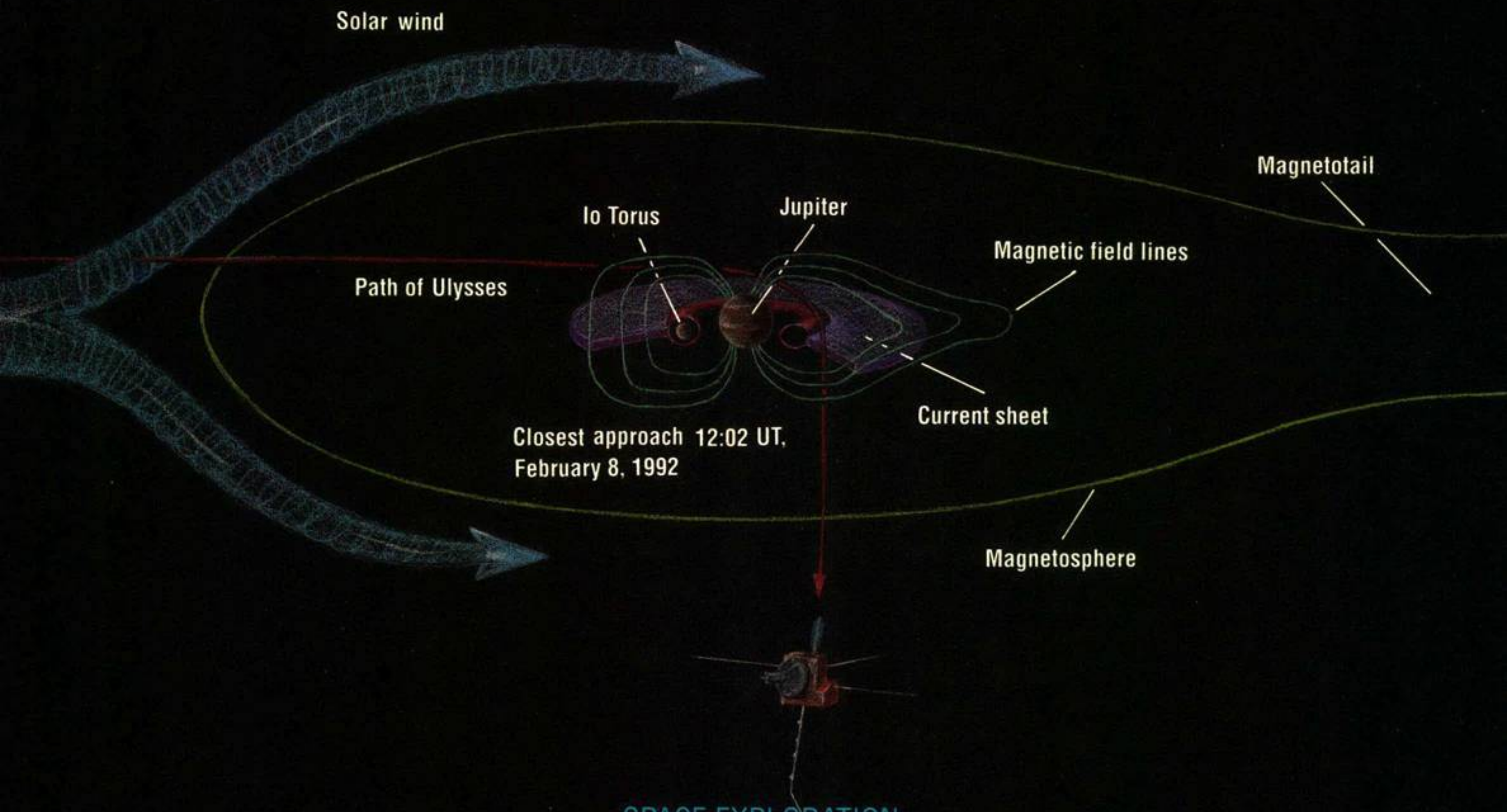
Other candidates come from the Hyades and the Pleiades, star clusters in the constellation Taurus. Previous searches with infrared detectors found no brown dwarfs down to a limit of 0.04 solar mass. Searches around white dwarfs found no brown dwarfs down to 0.03 solar mass in the Hyades and 0.0015 solar mass in the Pleiades. Infrared brightness measurements made by Claia Bryja and her colleagues at the University of Minnesota turned up 7 candidates in the Hyades. All of these objects appear around 17th magnitude and have a mass of 0.07 to 0.075 solar mass.

Bryja's brown dwarf candidates are tentative, because simple readjustments of the objects' brightnesses could yield stellar masses for the objects. And the 0.08-solar-mass border line between stars and brown dwarfs isn't well established. It may be as low as 0.075, or even 0.07, solar mass. Observers and theorists will be challenged by these 7 objects until they establish the identities of these objects as brown dwarfs or low-mass stars. Meanwhile Bryja and her colleagues continue to press toward fainter objects, hoping to glimpse unshakable brown dwarf candidates with masses of 0.06 solar mass.

The dearth of brown dwarfs is worrisome. There should be thousands of these objects scattered throughout the sky. Yet astronomers have detected few, if any, brown dwarfs. Unlike planets, brown dwarfs aren't hiding in the radial velocity noise created by a star's surface motions. Nor are their masses at the limits of detectability. The lack of detection may be more fundamental.

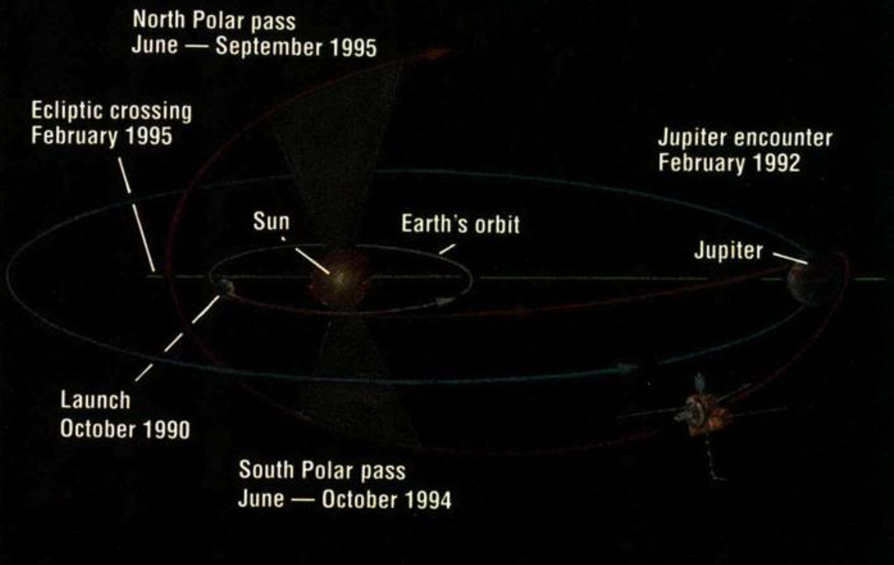
Gas clouds may not easily form low-mass objects such as brown dwarfs. So there may be a wide chasm between those objects we call stars and the planets that form around stars. Also, searches for brown dwarfs in binary systems may be doomed because some evidence indicates binaries form through the capture of companions instead of through fragmentation of a gas cloud into two objects. Perhaps brown dwarfs do form as single objects but are not easily captured into binary systems. Whatever the reason, brown dwarfs remain as elusive as planets.

Scientifically, all is not a bust. Although in many fields a lack of detection would prove worthless, here it does not mean no result. Further searches for planets and brown dwarfs, ever tightening the limits on the kinds of objects that can be out there, will tell us either how common planets are in the universe or that our system really is unique. Either is a winner because both answers tell us about how stars and planets form and draw us a little closer to understanding the mystery of how we got here. □


Solar wind
Magnetotail
Io Torus
Jupiter
Magnetic field lines
Path of Ulysses
Current sheet
Closest approach 12:02 UT,
February 8, 1992
Magnetosphere

SPACE EXPLORATION

ULYSSES MEETS A


North Polar pass
June — September 1995
Ecliptic crossing
February 1995
Jupiter encounter
February 1992
Sun
Earth's orbit
Jupiter
Launch
October 1990
South Polar pass
June — October 1994
KIRCHMEIER

ULYSSES SAILED A PATH (top) through Jupiter's flattened magnetic field that no other spacecraft had taken. It descended from a high northern latitude, swung behind the dusk side of the planet, then exited below the South Polar regions. Ulysses' new trajectory (right) will take it below the Sun's South Pole in 1994.

ASTRONOMY: Phil Kirchmeier, based on NASA artwork

GIANT

In early February, the tiny Ulysses spacecraft scouted the lair of a giant and escaped unscathed.

by Alan Dyer

Ulysses is off to explore a realm where no spacecraft has gone before — the polar regions of the Sun. The Ulysses probe is now racing on a course that in two years' time will take it below the Sun's south pole. But to turn onto that course, Ulysses had to steal energy from a potentially lethal giant.

Jupiter, known for deadly radiation belts, churning clouds, and a cyclopean red eye called the Great Red Spot, rules over a domain that ships dare enter only with great caution. But on February 8, 1992, Ulysses rounded the planet and braved the buffeting of its magnetic storms.

When Ulysses, the European-made space probe, flew past Jupiter in early February, it became the fifth spacecraft to reach the planet, following Pioneer 10 in 1973, Pioneer 11 in 1974, and Voyagers 1 and 2 in 1979. But Jupiter wasn't Ulysses' prime target. Jupiter's gravity was just a means to boost Ulysses' speed and bend its orbital path enough to fling it below the solar system. On its new course, Ulysses will be able to sample the magnetic fields and cosmic rays in the far southern (and eventually northern) reaches of the interplanetary ocean.

Sending a craft bristling with magnetometers and charged particle detectors past a planet with an intense magnetic field was a bonus too good to miss. Ulysses project scientists made the most of the opportunity and came away with a better picture of Jupiter's magnetic domain.

The Billion Amp Current

The region of magnetic fields around a planet is called the magnetosphere. Compared with Earth's magnetosphere, Jupiter's is very flattened, a shape molded by Jupiter's rapid 9 hour 54 minute rotation rate and by its volcanic moon Io.

Eruptions of Io's volcanoes spew atoms of sulfur and sodium into orbit around Jupiter where they lose their electrons — they become ionized. Jupiter's powerful magnetic fields trap these ions into a doughnut-shaped ring, or torus. Although Io takes about 42½ hours to orbit Jupiter, the charged particles that come from Io are caught by Jupiter's rotating magnetic field — they whip around the planet at the same rate as the planet rotates, roughly every 10 hours. With such a rapid acceleration, some of the ion particles are flung into a flat "current sheet" that, during the Ulysses flyby, extended nearly 3 million kilometers from Jupiter.

André Balogh, the project scientist in charge of Ulysses' magnetometers, estimates that at peak power a billion amps of electricity can flow along the current sheet. That much electricity humming around Jupiter generates its own magnetic field. Unlike the shape of the magnetospheres of other planets, the shape of Jupiter's magnetosphere is a combination of the more spherical magnetic field that comes from deep within the planet and the added magnetic field pulsing from its unique and flattened current sheet — thus the flattened magnetosphere. No other planet has a current sheet like Jupiter's because no other planet has a moon like Io, a ready source of ionized particles that feeds the current sheet.

Although Ulysses found the same magnetic structures as the Pioneers and Voyagers did, it confirmed that Jupiter's magnetosphere inflates and deflates over days and years. According the Balogh, "Ulysses found Jupiter's magnetic field much like the Pioneers did but much more extended than the Voyagers had found it." Some of the changes are from the varying strength of the solar wind that is constantly pelting Jupiter's magnetosphere. But some of the changes are modulated by the power level of the current sheet, which can vary by a factor of two. As Balogh explains, "This variation is almost certainly due to variations from Io." The Ulysses data suggest that the number and strength of the eruptions of Io's sulfur volcanoes can affect the size of the entire magnetosphere.

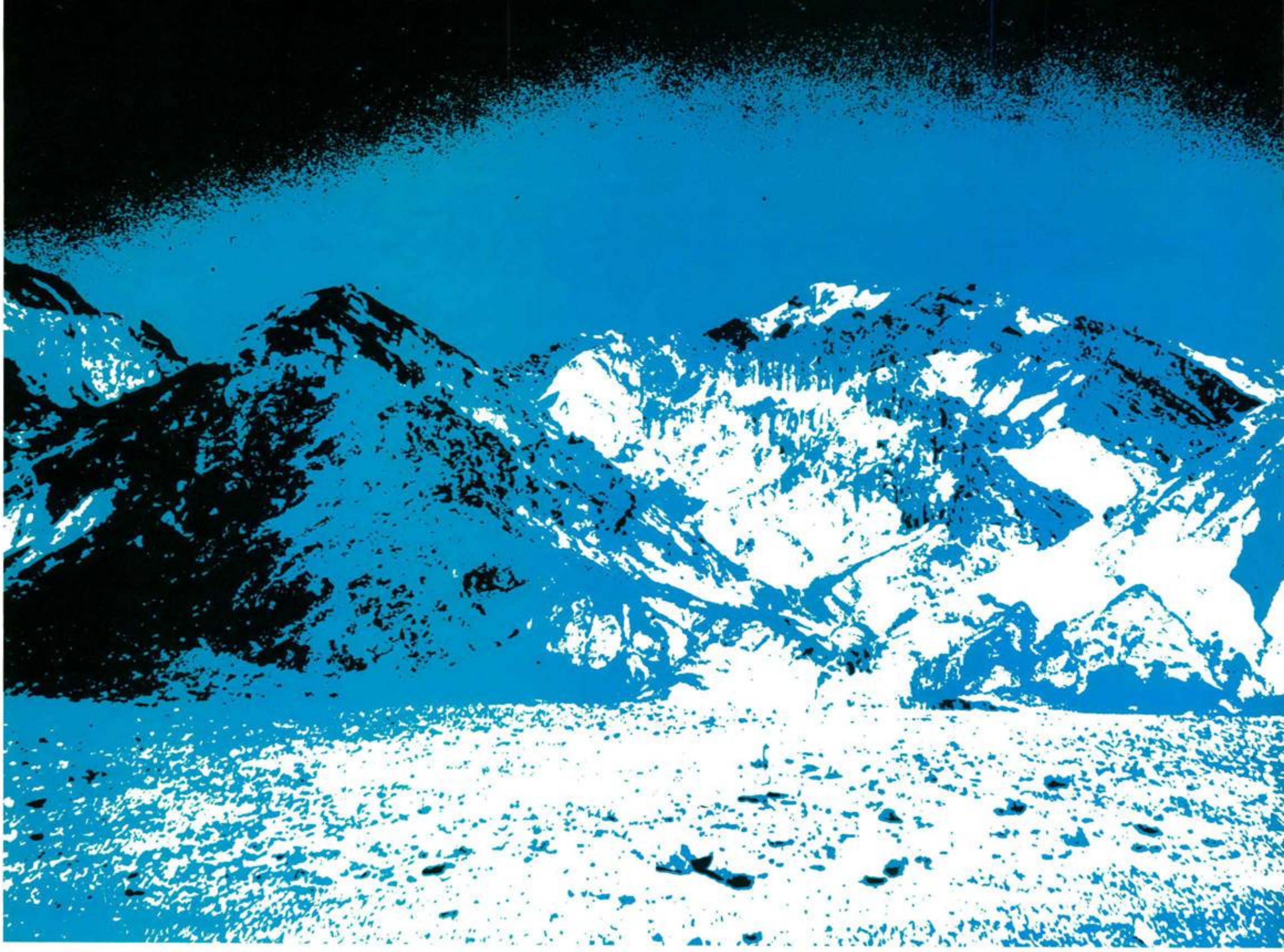
A "Pulsar" Close to Home

Throughout the Jovian encounter, Ulysses detected a sharp burst of high-energy electrons coming from Jupiter every 10 hours. "One of the exciting aspects of the Ulysses mission," explains project scientist John Simpson, "was that Jupiter was behaving like a pulsar."

Pioneer 10 first found the pulsing back in December 1973. When astronomers took those pulses as a starting point and counted the number of rotations over the intervening 18 years, they found that the times of the pulses detected by Ulysses were only 25 minutes off the predicted times.

But where do the pulses come from? The ten-hour period suggests a single source — one with two poles would sweep electrons by twice every rotation period or every five hours. The source of the high-speed electrons could lie in the nose of the magnetosphere where the solar wind collides with Jupiter's magnetic field, or somewhere in the polar regions close to Jupiter, or perhaps in the magnetic tail that stretches away from Jupiter. Whatever the mechanism, astronomers are sure that studying Jupiter's pulse rate will tell them a lot about how distant pulsars — fast-spinning neutron stars — send out their regular bursts of energy.

The intense radiation made the passage past Jupiter a dangerous maneuver for Ulysses. However, the craft escaped without a scar and is now sailing through the underworld of the solar system. ☐



will occur in that part of Earth's orbit that previously enjoyed summer. (Regular adjustments to the calendar keep the beginning of spring in the Northern Hemisphere fixed near March 21, so summer and winter will still occur during the same calendar months.) Slow changes in the shape of Earth's orbit also occur over a period of 93,000 years. And scientists still haven't discovered what causes periodic shifts of our climate into ice ages, the last of which ended around 20,000 years ago.

Life has adapted well to the changing cycles of Earth's seasons. But what if Earth's rotation axis tilted at an angle of 90° instead of 23½°? What would seasons be like on this tilted Earth?

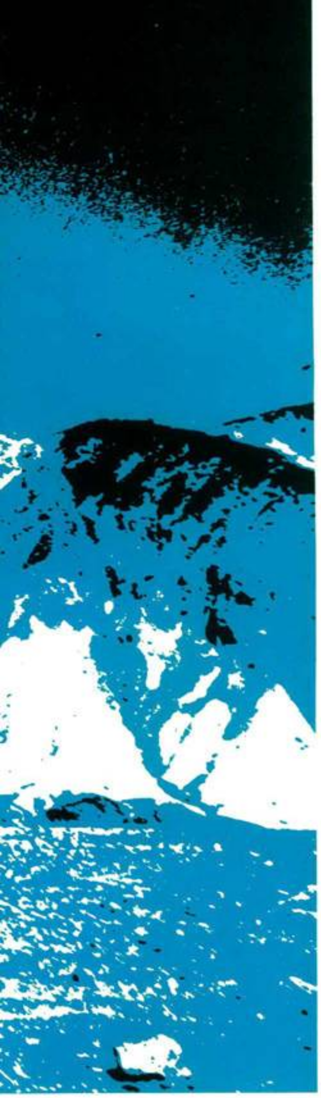
A Tilted Earth

Close your eyes and imagine a new Earth whose axis of rotation lies nearly in the plane of its orbit about the Sun, mimicking the rotation of Uranus. The new Earth still rotates once every 24 hours, but let us arbitrarily fix new Earth's north pole to point toward the star Chi^1 Orionis, which is a star in Orion's upraised right arm about 13° north of Betelgeuse. Chi^1 Orionis lies just below the ecliptic, which is the apparent path of the Sun through the sky as a result of Earth's orbit about the Sun. Earth's south pole points toward Beta Virginis (Zavijava).

It's March 21, the date of the spring equinox on new Earth (and old Earth). The equinox, which means equal night, is one of the two days of the year when the Sun appears directly over Earth's equator. Every location on Earth has nearly twelve hours of day and night near the equinox. (Although equinox means equal day and night, day and night aren't exactly equal on the equinox for two reasons: Earth's atmosphere bends sunlight so sunrise appears earlier than it would without the atmosphere, and the appearance of the Sun's upper limb defines the moment of sunrise, so sunrise occurs slightly earlier than if astronomers used the Sun's center.)

For the next three months, the Sun rises higher in the sky of the Northern Hemisphere. The north pole constantly points toward Chi^1 Orionis. But instead of appearing directly overhead at a maximum of 23½° north latitude as it does for old Earth, the Sun now appears over the north pole of new Earth at the summer solstice, around June 22. Three months later, at the autumnal equinox, the Sun again rises over the equator and day and night have the same length everywhere on Earth. The Sun appears over the south pole of new Earth at the winter solstice, which is around December 22. The Sun's apparent motion through Earth's sky completes the seasonal cycle by moving north, appearing over the equator once again around March 21. (The cycle of seasons for Southern Hemisphere observers is opposite, with the summer solstice occurring in December and the winter solstice in June.)

Day and night take on new meanings for inhabitants of new Earth. On old Earth, only those lands above the arctic and antarctic circles have days or weeks of continual light in summer and days or weeks



Dave Bruning

Spring brings tropical heat to the mid-latitudes of an Earth tilted like Uranus, while summer brings months of continual daylight and scorching heat to the poles.

of constant darkness in winter. But on new Earth, every place has extended winter periods of constant darkness followed by extended summer periods of constant daylight. (The equator is a notable exception. It has extended periods of dusky twilight during summer and winter.) Spring and fall have daily cycles of daylight and darkness, which separate the periods of continual daylight and darkness.

For example, imagine you live in Atlanta, Georgia, on new Earth. On March 21, with the Sun over the equator, you have twelve hours of daylight followed by twelve hours of darkness, just like the citizens of Atlanta on old Earth. Day by day as spring unfolds, the Sun rises higher in the sky. On April 25 as you look outdoors at noontime, you see the Sun on your zenith, or directly overhead, which is something that old Earth Atlantans never see. The United States — as every mid-latitude country — on new Earth experiences tropical heating from the Sun's beating straight down. Spring temperatures soar compared with those on old Earth.

As the year marches on, the Sun passes north of the zenith at noon. May 19 marks the day for citizens of the new Atlanta when the Sun no longer rises and sets every day. Instead it remains above the horizon all day and continues to do so for the next 68 days. The cycle of daylight and darkness does not return until July 26.

At the summer solstice around June 22, the Sun appears farthest north. To new Atlantans, it appears 56° north of the zenith at noontime, or just 34° above the northern horizon. Then it will start southward, passing overhead again in Atlanta on August 18. As the Sun appears progressively lower in the southern sky at noontime, it finally dips below the horizon on November 17. This starts a 68-day-long period of darkness and a prolonged and exceptionally cold winter.

So in Atlanta on new Earth, the day-night cycle takes place for 7½ months out of the year. For the other 4½ months there is continuous day or continuous night, coupled with harsh summers and winters. All forms of life have to adapt to the extremes of the light-dark, warm-cold cycle that new Earth presents.

With variations on the dates and lengths of the periods of prolonged daylight and darkness, this sequence of events occurs everywhere on new Earth. The seasonal heating cycle prevents the formation of permanent polar ice caps. The polar regions experience the same tropical heating and high temperatures as the equatorial regions of old Earth. However, the polar regions in winter are exceptionally cold, so seasonal polar ice caps may form. Because the polar caps aren't permanent, the oceans — and the shorelines on the continents — are higher than those on old Earth.

If seasonal polar ice caps form, the dominant force controlling weather may shift from jet streams which circle Earth along lines of latitude to a pole-to-pole flow. This mimics the condensation flows seen on Mars, caused by the freezing and thawing of the Red Planet's polar caps. Thermal flows created by intense heating at one location and cooling at others may replace old Earth's trade winds and other east-west winds.

New Earth residents probably also experience significant seasonal variations in the shoreline, depending on whether the thawing of one polar ice cap occurred at the same rate as freezing at the other pole. This change in sea level would occur on top of a change in the range of tides due to gravitational effects from the Moon and Sun.

Ocean Tides

The Moon causes about two-thirds of our tides and provides the main focus for our discussion. (The Sun's gravity provides the rest of the tidal effect.) Since the force of gravity decreases with distance between two objects, the Moon pulls on Earth's near side more than the center. The stronger pull on the near-side landmass raises it by as much as 20 centimeters compared to Earth longitudes 90° away. A second tide is raised on the side opposite from the Moon, because the Moon's gravity pulls on Earth's center more strongly than on the far side. The Moon effectively pulls the center away from the far side, raising the far-side landmass by as much as 20 centimeters.

Earth's rigid, rocky material resists the distortion of the Moon's gravity, so the landmass tides are rather unremarkable. But water flows easily, so the Moon's gravity raises ocean tides on average by about 1 meter. Bays can accumulate tidal waters of up to 10 meters.

We can visualize the gravitational interaction between Earth's oceans and the Moon as made of three

Seasonal ice caps form at Earth's poles during the long winters of continual darkness and frigid temperatures.

parts: the oceans on the side nearest the Moon, the body of Earth, and the oceans on the side farthest from the Moon. The Moon pulls on the near-side oceans more strongly than it pulls on the Earth's body. As a result, the tidal forces pull these oceans away from the body, creating a high tide. To an Earth observer, high tide occurs when the Moon appears high in the sky. The regions on Earth 90° away from the area of high tide experience low tide, because water has been drawn from these regions to make high tide elsewhere. The Moon's gravity in the low tide region pulls along the surface toward the Moon and the region of high tide.

Similarly, the Moon pulls Earth's body away from the oceans on the far side, creating high tide. So to the observer on Earth, high tides exist when the Moon is directly overhead and when it is on the other side of Earth. High tides occur roughly 12 hours and 25 minutes apart, so there are almost two cycles of high and low tide each day. The tide cycle isn't exactly twice a day because the Moon orbits around Earth in the same direction as Earth rotates on its axis. It takes the orbiting Moon 50 extra minutes to catch up with the rotating Earth, thus crossing overhead in 24 hours 50 minutes instead of exactly 24 hours. (The two cycles of tides created by the Sun are 12 hours long.)

Tides are significantly different on new Earth compared with the simple rising and falling tides of old Earth. New Earth's tides are much more complex, even though the Moon remains in the same orbit. The Moon's orbital plane lies roughly along the ecliptic, so both the Moon and Sun tug primarily on old Earth's equatorial regions. But new Earth's rotation axis lies along its orbit — that is, it points to a spot along the ecliptic — so the Moon doesn't orbit around the equatorial regions. Rather, the Moon has a polar orbit, passing over both of the Earth's poles as well as twice over the equator during each orbit.

Tides (on either Earth) have essentially two interacting cycles. The Moon pulling on the spinning Earth establishes the almost twice-daily cycle. The relative positions of the Sun and the Moon determine how high the tides are each day. Spring tides occur when the Sun and Moon line up, since the gravities of the two bodies add together to create larger tidal forces. Neap tides occur when the Sun and Moon are at right angles to one another as seen from Earth. In this case, the gravitational forces counteract each other, creating weaker tidal forces.

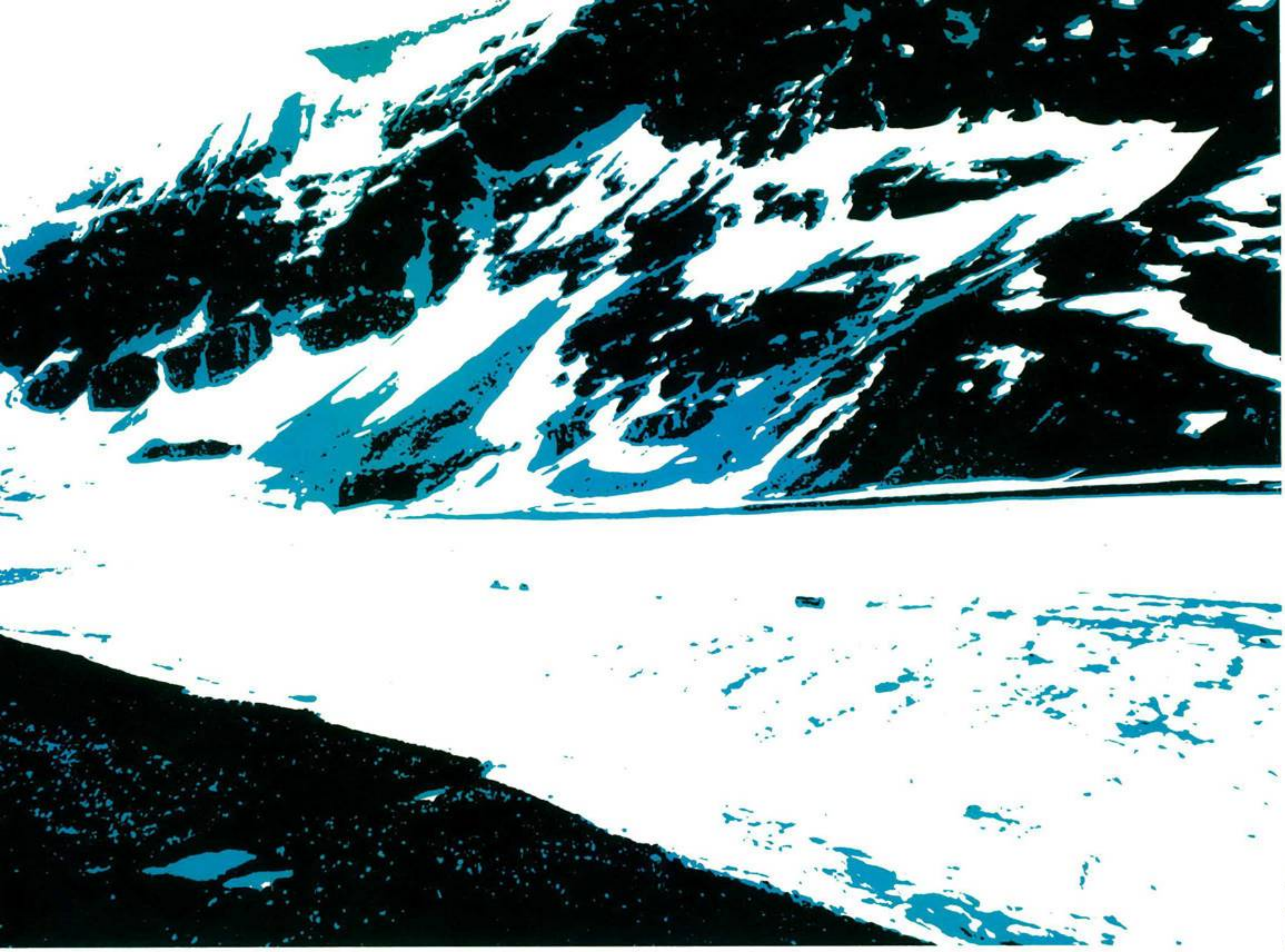
When both the Sun and the Moon are over new Earth's equator, spring tides occur. It doesn't matter whether the Sun and Moon are on the same side of Earth or on opposite sides, because only the relative forces exerted on the oceans and Earth's body count. So spring tides have the same height on both sides of Earth whether the Sun and Moon are on the same side of Earth or on opposite sides.

As the Moon orbits Earth every 29½ days, the region of high tides follows along. The ocean region with the highest tides (ignoring shoreline effects) always occurs at the latitude at which the Moon appears directly overhead. As the Moon passes over the polar regions, observers there on new Earth experience high tide, unlike on old Earth where the polar regions never see very large tidal effects.

When the Moon appears overhead to an observer on new Earth's equator, the tidal cycle consists of nearly two high tides and two low tides every day. Earth's rotation carries the observer through the different regions of strong tidal forces, creating the high tides and low tides. When the Moon and Sun appear at right angles as seen by an observer on new Earth, the height of the high tide is lowest, resulting in a neap tide. But when the Moon appears overhead to an observer at one of the poles, there is little change in the height of the tide during the day. The tide remains high because Earth doesn't rotate underneath the Moon.

With the Moon over one of new Earth's poles, the dominant cause of changing tides is the Sun, and the period between "high" tides will change from 12 hours 25 minutes to just 12 hours. The size of the Sun-driven tide is just one-half the size of the lunar tidal variations. There even are days on new Earth when both the Moon and Sun are over Earth's poles, providing absolutely no change in height of the oceans anywhere on Earth.

Observing the Moon from new Earth is different. The Moon still goes through its cycle of phases, from New Moon to Full Moon and back to New Moon. The Moon still traces its way through the constellations of the



Dave Bruning

zodiac. But where it appears in an observer's sky is vastly different. The Moon is no longer confined to a path stretching from east to west, as observed from old Earth. Instead, observers can see it virtually anywhere in the sky from north to south.

Adapting Life-Forms

Creating a new world tempts one to populate it and see how the life-forms on it survive and adapt. One of my favorite speculations regards the impact of new Earth's dramatically changing cycles of light and dark on the development of biological clocks. Biological clocks, also called circadian rhythms, help animals and plants make the best use of their waking hours, driving urges to eat, sleep, seek shelter, or store food for the winter.

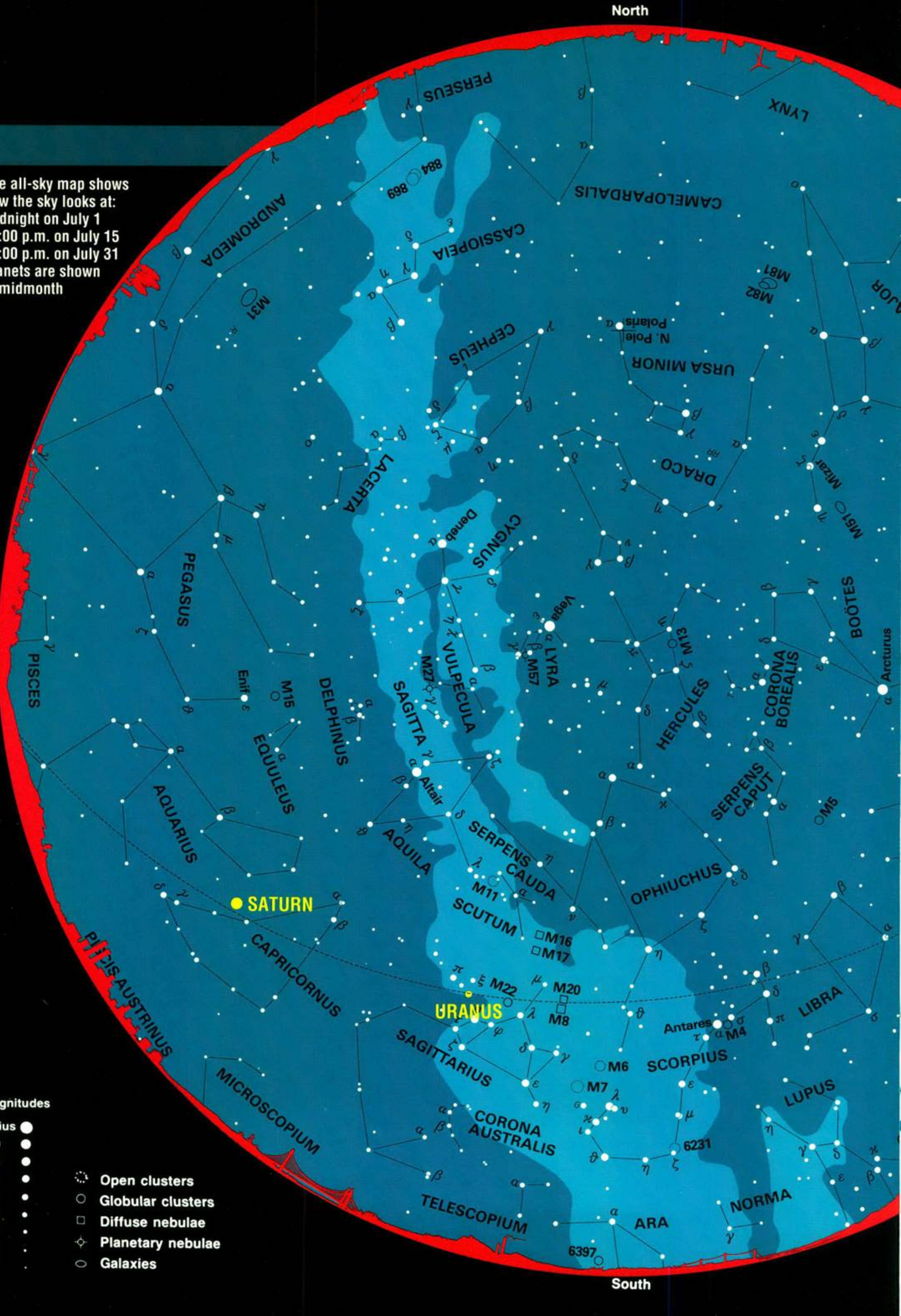
For millions of years, the day has been about 24 hours long on old Earth. (It's getting longer as the ocean tides, rubbing against the landmass, slow Earth's rotation.) Most living things have biological clocks that run with cycles of between 23 and 25 hours. Earth's cycle of day and night constantly realigns these cycles to keep them in sync with the changing seasons. In contrast, during experiments in which no day-night change occurs in lighting, people resort to their natural biological clock of around 25 hours to regulate their actions, such as sleep cycles.

But life on new Earth, where protracted periods of daylight and darkness exist, would have to adapt differently. Life-forms may depend exclusively upon their biological clocks to avoid the problem of the changing day-night cycle and the periods of prolonged daylight and darkness. Or perhaps the biological clocks would take over only during the periods of continual daylight and darkness. When day and night cycles finally returned, the day-night cycle would control activities. (Would life-forms suffer from a massive dose of jet lag during the period when the day-night cycle takes over from the internal biological clock?) Perhaps life wouldn't have biological clocks at all. Or perhaps life-forms would have a complex set of rhythms that control activities during the periods of prolonged darkness and prolonged light and that adjust to changes in the day-night cycle. Clearly, whatever dominates the biological rhythms, social and emotional aspects of humans would evolve differently on new Earth.

Though we don't often think about the tilt of Earth's rotation axis, it impacts the seasons, tides, and many complex biological phenomena. Earth's moderate temperatures result from its rather uniform heating and the storage of heat by the oceans. We should consider ourselves lucky that Earth doesn't have an inclination like that of Uranus, because winters would be long periods of darkness and frigid cold, and summers would be equally long periods of constant daylight and tropical heat. □

Neil F. Comins is an associate professor of physics at the University of Maine. His last article was "Life around a Larger Sun" in the May issue.

The all-sky map shows how the sky looks at:
Midnight on July 1
11:00 p.m. on July 15
10:00 p.m. on July 31
Planets are shown at midmonth


North
PERSEUS
LYNX
CAMELOPARDALIS
CASSIOPEIA
869
884
ANDROMEDA
M31
M81
M82
CEPHEUS
N. Pole
Polaris
URSA MINOR
LACERTA
DRACO
Mizar
M51
Deneb
CYGNUS
PEGASUS
Vega
LYRA
M57
VULPECULA
M27
BOÖTES
M13
HERCULES
CORONA BOREALIS
Arcturus
East
PISCES
Enif
M15
DELPHINUS
EQUULEUS
SAGITTA
Altair
AQUARIUS
AQUILA
SERPENS CAUDA
SERPENS CAPUT
M5
OPHIUCHUS
SATURN
M11
SCUTUM
M16
M17
CAPRICORNUS
PISCIS AUSTRINUS
M22
M20
M8
URANUS
LIBRA
Antares
M4
SAGITTARIUS
M6
SCORPIUS
M7
MICROSCOPIUM
LUPUS
CORONA AUSTRALIS
6231
TELESCOPIUM
ARA
NORMA
6397
South
Magnitudes
Sirius
0.0
0.8
1.6
2.4
3.2
4.0
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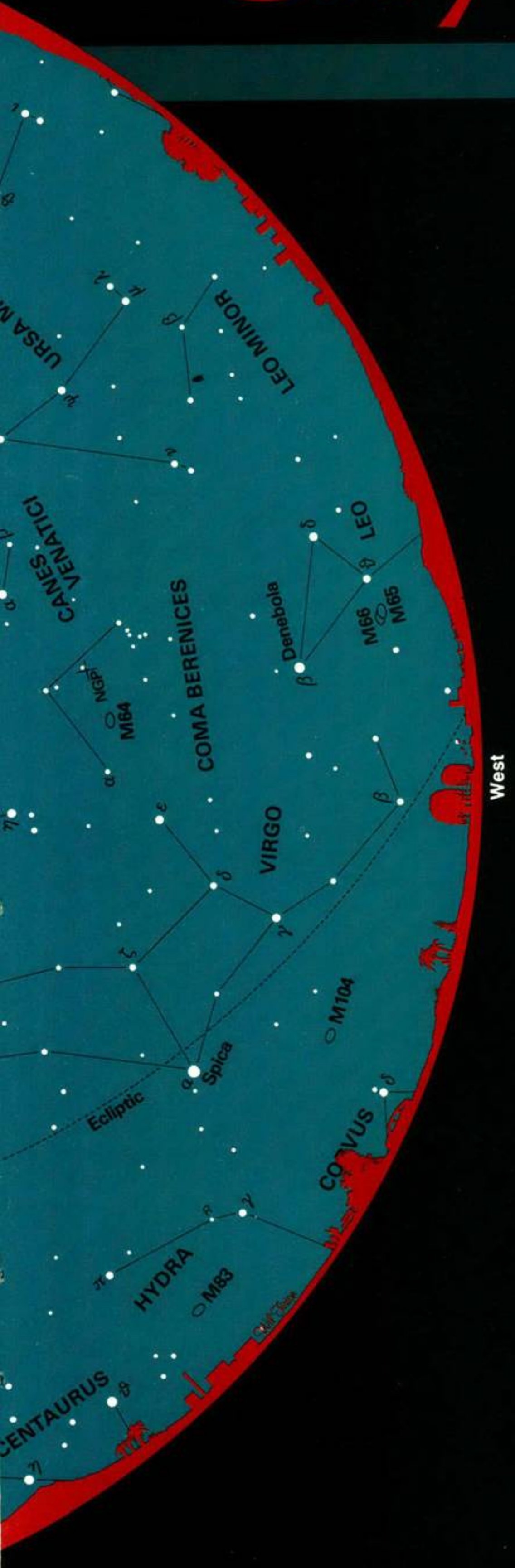
5.6
Open clusters
Globular clusters
Diffuse nebulae
Planetary nebulae
Galaxies

Sky Almanac

July 1992



DELTA AQUARID METEORS

Because the Perseids are obliterated by a nearly Full Moon this year, try observing another meteor shower — the southern Delta Aquarids. This little-known shower peaks on July 28, when in the early morning sky you might spot as many as 20 meteors per hour. Take your sleeping bag, a mug of warm cocoa, and head out for the realm of the shooting stars!

ATTENTION MERCURY SPOTTERS

One of the best opportunities of the year to spot the elusive planet Mercury occurs in the early evening sky this month. The little orange planet reaches greatest eastern elongation on the evening of July 5, when some 26° will separate it from the Sun. To spot Mercury, take a pair of binoculars outside after sunset and carefully scan near the western horizon. After you spot Mercury, try seeing it with eyes alone.

A MONTH FOR OCCULTATIONS

The Moon occults both Neptune and the bright star Theta Ophiuchi this month for observers in the United States. Early on the morning of July 14, observers in the western and central United States will see Neptune slip behind the lunar disk. The planet will reappear about an hour later. Just after midnight on the 12th, the Moon occults the 3rd-magnitude star Theta Ophiuchi, above the stinger of Scorpius.

Calendar of Events

1 The Moon is at perigee (223,987 miles from Earth), 9 p.m. EDT

5 Mercury is at greatest eastern elongation (26°), 9 p.m. EDT

6 First Quarter Moon is at 10:43 p.m. EDT

7 Uranus is at opposition, 7 p.m. EDT

9 Neptune is at opposition, 9 a.m. EDT

12 Theta Ophiuchi is occulted by the Moon

14 The Moon passes 1.8° north of Uranus, 2 a.m. EDT

Neptune is occulted by the Moon, 5 a.m. EDT

Full Moon is at 3:06 p.m. EDT

16 The Moon passes 5° north of Saturn, 7 p.m. EDT

17 The Moon is at apogee (252,181 miles from Earth), 7 a.m. EDT

22 Last Quarter Moon is at 6:12 p.m. EDT

25 The Moon passes 4° north of Mars, midnight EDT

Ceres is at opposition, 6 p.m. EDT

28 Southern Delta Aquarid meteor shower peaks

29 New Moon is at 3:35 p.m. EDT

30 The Moon is at perigee (222,157 miles from Earth), 4 a.m. EDT

Eye on the Sky

by Deborah Byrd

URANUS AT OPPOSITION

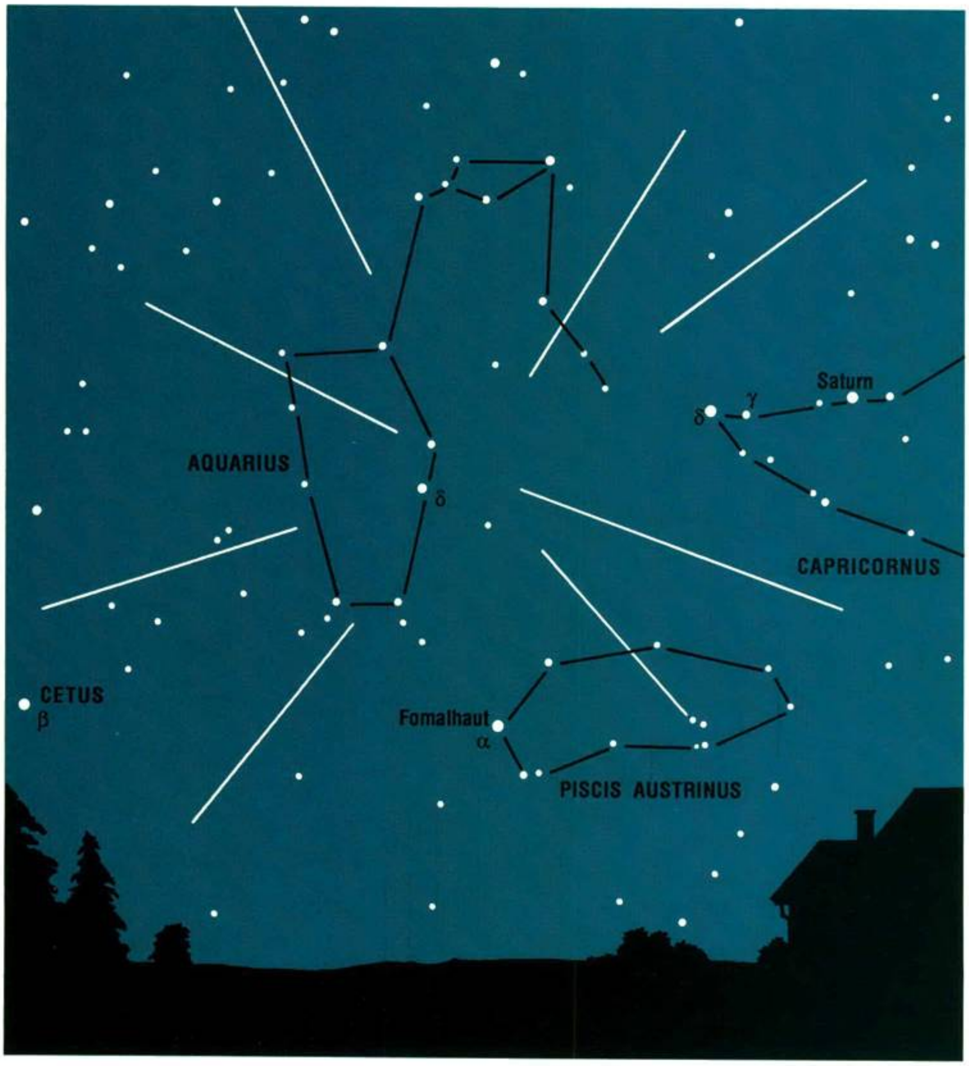
None of the usual reasons for enjoying a planet without optical aid apply to the planet Uranus. Although four planet Earths could be placed side by side in front of Uranus, this planet is extremely remote from us at a billion-and-a-half miles away. It doesn't appear bright in our sky, change significantly in brightness, or move rapidly in front of the stars. Some planets appear striking when near Earth's Moon, but bright moonlight only drowns Uranus from view. The greatest thrill to be had from Uranus is merely seeing it!

And yet even a glimpse of this remote outer world can be memorable. If you've not yet seen the planet, this is the best month all year to do so. Uranus comes to opposition on July 7. That is the evening when Earth flies between it and the Sun. At opposition, Uranus rises at sunset and casts its dim light in the heavens all night long.

The planet lies in the star-rich constellation Sagittarius. It stands apart from the glittering stars because it shines steadily, with a greenish color. Stars rarely (some say never) appear green.

Uranus shines at magnitude 5.6. Look for it in a dark sky, far from city lights, on a night when the Moon is down. Search with binoculars first, but once you have found the planet, lay the binoculars aside for a glimpse of Uranus with the naked eye. Then try the binoculars again. Do they intensify the greenish color of this world? Notice that even with binoculars you cannot see Uranus as anything more than a point of light.

SUMMER METEORS are visible this month when the Southern Delta Aquarids peak. The shower attains maximum activity on July 28, when under a dark sky you can spot as many as 20 meteors per hour.



An amazing fact about Uranus is that its axis of rotation is tipped almost parallel to the plane of the solar system. In 1985, we viewed this planet's south pole almost directly pole-on, and things have not changed much since then. Uranus has at least fifteen moons, all smaller than Earth's Moon, orbiting in the plane of the planet's equator. Large telescopes are needed to see these moons, but imaginations can be employed to think about them. With the moons' orbits face-on to Earth, the Uranian system can be imagined as being rather like a target, with Uranus itself at the bull's eye.

By the way, another outer planet lies just a few degrees from Uranus on the sky's dome now, but you can't glimpse Neptune with the unaided eye. Neptune and Uranus are about the same size, but Neptune is nearly a billion miles farther away when it's at opposition on July 9.

MERCURY AT GREATEST ELONGATION

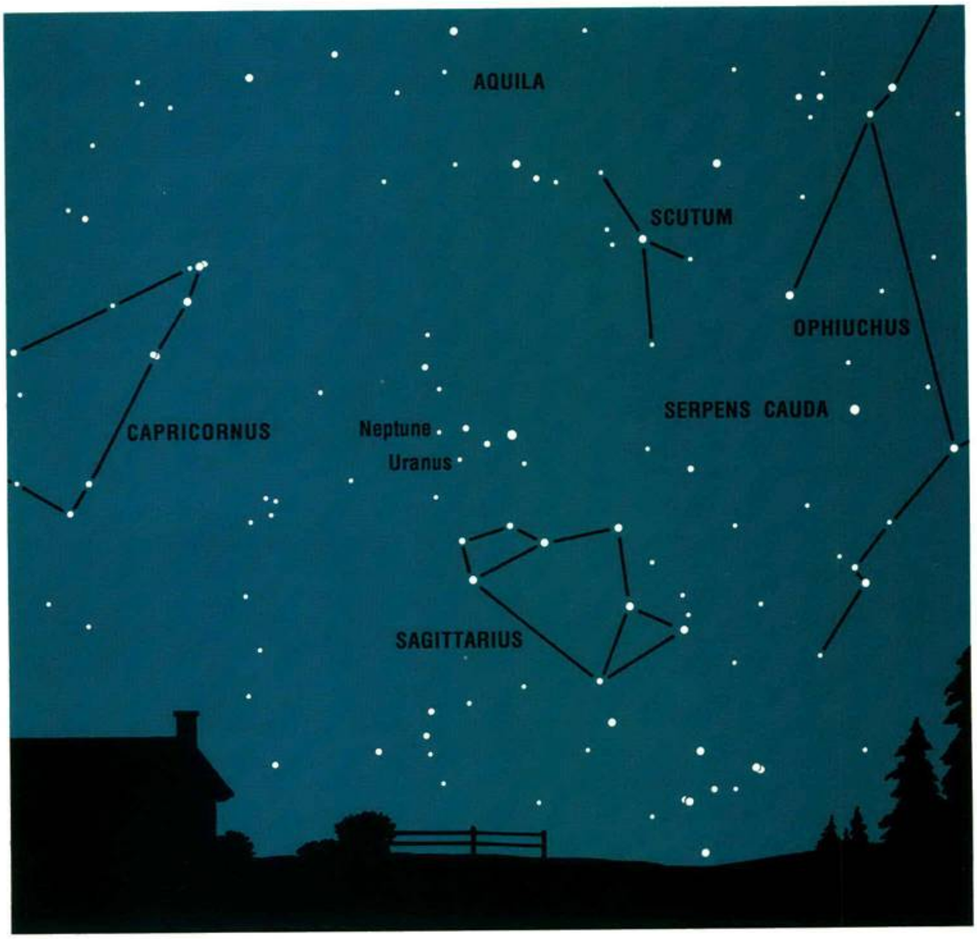
When July opens, the innermost planet Mercury is in the middle of a long evening apparition. Look for the planet low in the west-northwest no later than about 45 minutes after sunset. The planet shines at magnitude 0.3 when the month begins. The waxing crescent

Moon sweeps left of Mercury on July 2. Greatest elongation — Mercury's greatest apparent distance from the Sun on the dome of our sky — comes on July 5. Then the planet is 26° east of the Sun.

A much brighter planet can be seen above and left of Mercury this month. Jupiter shines like a beacon at magnitude –1.8. The bright star between Mercury and Jupiter is Regulus, in the constellation Leo. After greatest elongation, Mercury begins sinking rapidly toward the western horizon after sunset. It fades rapidly in brightness and thus becomes increasingly difficult to see in the twilight glare. Meanwhile, Jupiter and Regulus are drawing closer to Mercury as they also plunge toward the western horizon. Jupiter begins the month about 30° from Mercury, but it is closer to the planet when Mercury disappears around mid-month.

SUMMER METEORS

Late July and early August generally are wonderful times of year for watching meteors. The nights are warm, and two major showers — the Delta Aquarids and the Perseids — join forces to produce some fabulous displays. This year the Full Moon on August 13 will interfere with the peak of the Perseids. But since the parent comet of the Perseids is predicted by some to return this year and since great meteor storms can often accompany the return of such a comet, this is an excellent year to watch for meteors more than once!



URANUS AND NEPTUNE come to opposition on July 7 and 9, respectively. Uranus is visible to the naked eye as a 6th-magnitude "star." Neptune's 8th-magnitude glow is visible in binoculars and small telescopes.

Start watching on some clear morning in late July, around the time of New Moon on July 29. The Delta Aquarid shower has its ill-defined peak around then. This shower may actually produce a greater total number of meteors than the Perseids, but the shower is less widely known because it lacks a sharp peak. Don't forget: you will see more meteors in a dark country sky, in the hours after midnight.

It's no problem telling a Perseid meteor from a Delta Aquarid. Just remember that meteor names are derived from the point in our sky from which they appear to radiate. You'll see meteors in all parts of the sky, but take note of the direction from which they come. If you are watching before dawn, and the meteors fly from the southwest, they are Delta Aquarids. If they come from the northeast, they are Perseids.

JULY'S PLANETS

Mercury is low in the west after sunset when the month begins. Look for it about 30 minutes after the Sun goes down. It'll be shining at about magnitude 0.3 when the month begins. A good time to see Mercury is around July 2, when the Moon sweeps nearby. A few days later, on July 5, Mercury comes to greatest elongation. Then it is farthest from the Sun on the starry dome for this evening apparition.

Jupiter is still very bright, but it's clearly sinking lower in the west each evening. Soon it will sink out of sight. This is happening because Earth has now moved far ahead of Jupiter in the race of the planets around the Sun. Our motion will bring the Sun between us and Jupiter in September. Jupiter now shines at magnitude –1.8. It is still in front of Leo, not far from Regulus, Leo's brightest star. Look for the waxing crescent Moon near Regulus and Jupiter around July 3 and 4. An even younger Moon appears 8° below Jupiter on the evening of July 31.

Saturn, in Capricornus, rises near the end of evening twilight on July 1 and earlier as the month progresses. Saturn will reach opposition in August. The best time to see this planet is almost upon us. This month Saturn shines at about magnitude 0.3. Look for the Moon near Saturn on July 16.

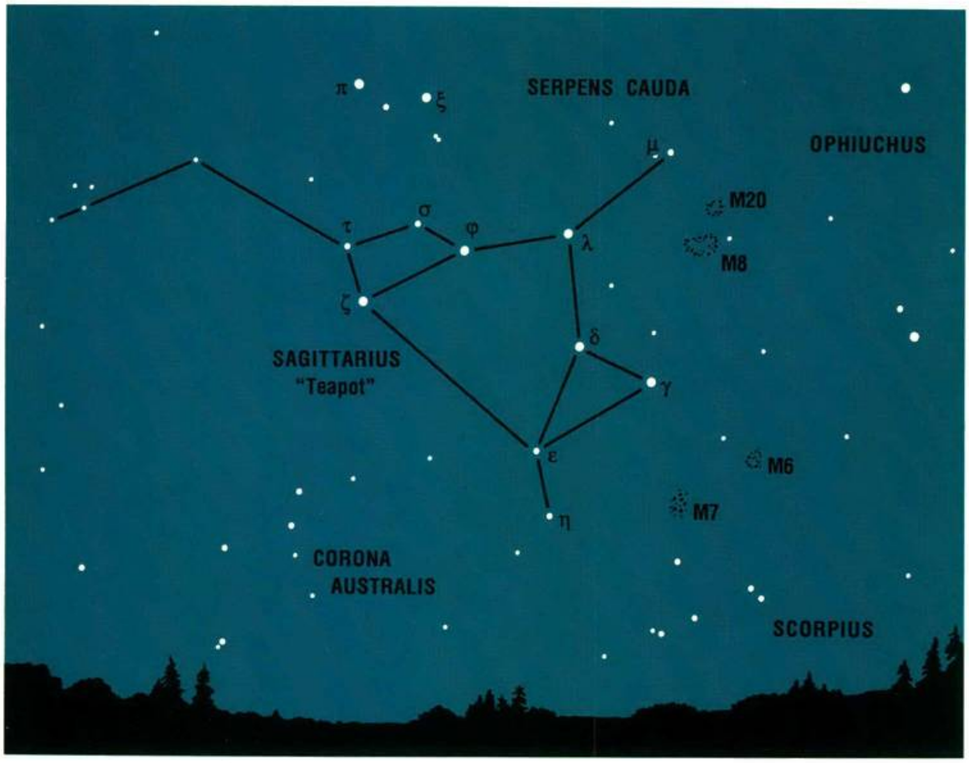
By the way, Saturn is famous for being the planet with the widest and brightest system of rings. But in the last couple of decades, studies made of Saturn by spacecraft have revealed that the rings probably didn't form with the planet. Now it's estimated that Saturn's rings have a history of only about 100 million years. That means that if the dinosaurs had had telescopes when they ruled the Earth, they would have seen a ringless Saturn!

Mars is still coming up in the wee hours, but it has now climbed a respectable distance from the light of dawn and brightened to magnitude 0.8. Mars passes from the constellation Aries to Taurus in mid-month. It is creeping toward Aldebaran, the bright reddish star at the heart of the Bull. On the morning of July 25, Mars appears in a striking arrangement with the Moon and the Pleiades star cluster.

Before the month ends, another planet — the brightest of them all — comes into view low in the evening twilight sky. **Venus** shines at magnitude –3.9. It can be seen very near the western horizon, shining brilliantly, about 30° to the lower right of Jupiter.

THE STARRY SKY

As you gaze toward Uranus this month, you're looking toward a region of the heavens not only beautiful to see, but also wonderful to contemplate. Uranus is located in front of the constellation Sagittarius, whose stars represent a mythological archer. This part of the sky marks the direction to the star-rich center of our own Milky Way Galaxy.



SAGITTARIUS THE ARCHER is one of the brightest constellations in the summer Milky Way. It is chock full of clusters and nebulae, many of which are visible in binoculars.

In Greek mythology, Sagittarius was associated with Chiron, one of the legendary centaurs. Most centaurs were said to be wild, quarrelsome, and destructive, but Chiron was friendly and wise, and skilled in hunting, music, and medicine. He is said to have been tutor and foster father of Aesculapius, the physician whose story we told last month. Chiron was also a friend to Hercules. It's said that Chiron met his death during a battle between Hercules and the centaurs. He was accidently struck by one of Hercules' poisoned arrows. Chiron was immortal and thus, to the gentle centaur, the wound would mean never-ending pain. When he asked Zeus to allow him to die, the king of the gods placed him among the stars. □

Deborah Byrd's radio series, "Earth and Sky," can be heard on stations in the United States, Canada, and Guam.

Through the Eyepiece

by Jeff Kanipe

URANUS AT OPPOSITION

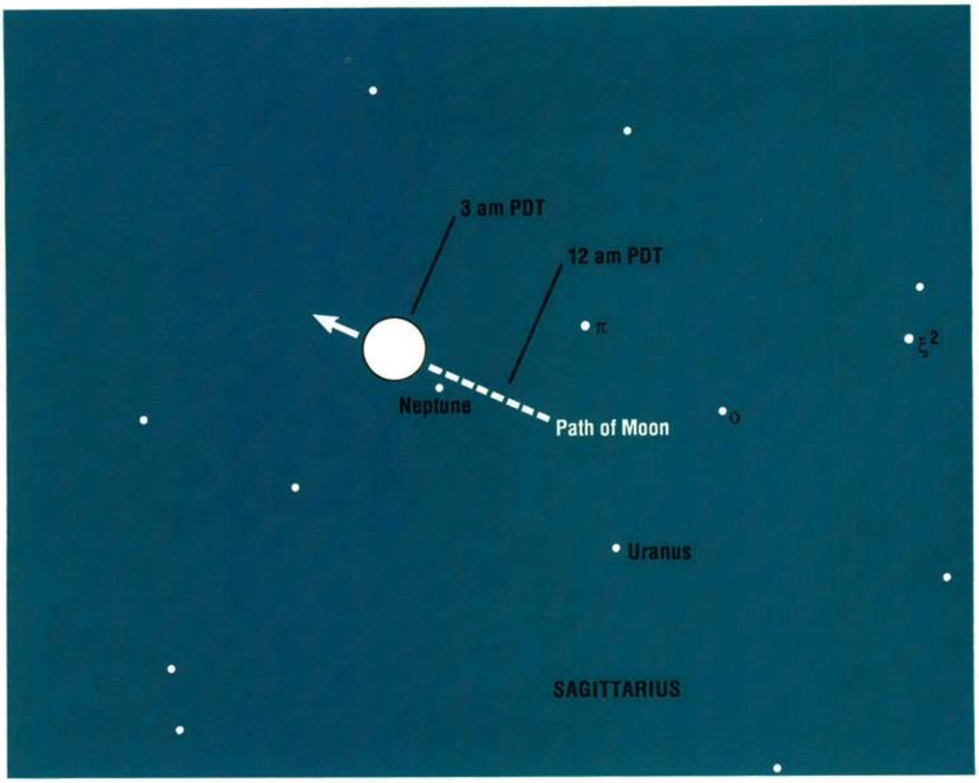
Sir William Herschel was toiling away at mapping the stars from his backyard in 1781 with his modest (and homemade) 6-inch reflector when he came across an unusual blue-green star. Like any good observer, he increased magnification. When he did so, the object's size also increased, and sharp-eyed Herschel had the strong impression that he was seeing an extended object, while the stars remained points of light.

At first he thought it was a comet, but it later proved to be a world, Uranus, and Herschel became famous. Subsequent orbital calculations showed that the planet had been mistaken for a star on no less than 22 occasions during the century preceding its discovery; it was even recorded as the star 34 Tauri on one of Flamsteed's old charts. As the late 19th-century astronomy popularizer Henry White Warren said of these nearly two dozen failures: "Eyes were made not only to be kept open, but to have minds behind them to interpret their visions."

Hopefully, your eyes and mind will work in sync this month as Uranus comes to opposition on July 7. On that night, it rises in the southeast at sunset and rides high in the south by midnight. Look 5° northeast of the teacup handle in Sagittarius or, more specifically, 2° south of Omicron Sagittarii. This is quite a busy little area of sky this month, for just about 2° farther east lies Neptune, which not only comes to opposition two days after Uranus but is also occulted by the Moon for some observers in the United States.

Uranus' magnitude at opposition is 5.6, making it just visible to the naked eye in a dark, rural sky. Considering the star-crowded region Uranus is in, however, there is little hope of distinguishing it from other stars of similar brightness. Binoculars make this task easier, but you can see the planet so much better with a small telescope. At the very least, it won't look like a star: with a diameter of about 32,000 miles, Uranus appears as a 3.8"-diameter disk at its current distance of 1.7 billion miles.

A 3-inch refractor is powerful enough to reveal Uranus' more-or-less greenish disk, a color attributable to the planet's methane-rich atmosphere, which absorbs red light. This color becomes even more apparent in an 8- or 10-inch telescope at high magnification. Though no atmospheric features are visible, Uranus is nevertheless an uncanny sight in the eyepiece, especially on nights of steady seeing when the disk is clearly resolved. After you grow accustomed to seeing the likes of Mars, Jupiter, and Saturn in the eyepiece, this blue-green specter seems somehow unnatural floating among the stars.



THE MOON OCCULTS NEPTUNE in the early morning sky on July 14. Observers in the central and western United States will see the Moon's disk cover the distant planet for an interval of about one hour.

OCCULTATIONS OF NEPTUNE AND THETA OPHIUCHI

The same might be said of 8th-magnitude Neptune, which comes to opposition on July 9. Neptune, however, appears more starlike than Uranus, and magnifications of at least 200x are needed to resolve its blue disk in an 8-inch reflector. Although Neptune is fun to locate, that's about the extent of it, unless you want to count the fact that it's more turquoise than Uranus!

Something else interesting happens to Neptune five days later, though. During the morning hours of July 14, the Full Moon occults Neptune for observers in Hawaii and in the western and central United States. Despite the glare, Neptune should be visible just northeast of the Moon's disk around 8h30m UT (1:30 p.m. PDT). The planet disappears behind the Moon around 9h UT. Once you've located the planet, use moderate to high magnifications and track it as it slips behind the lunar disk. The planet reappears in certain locales an hour or so later (the timing depends on your location).

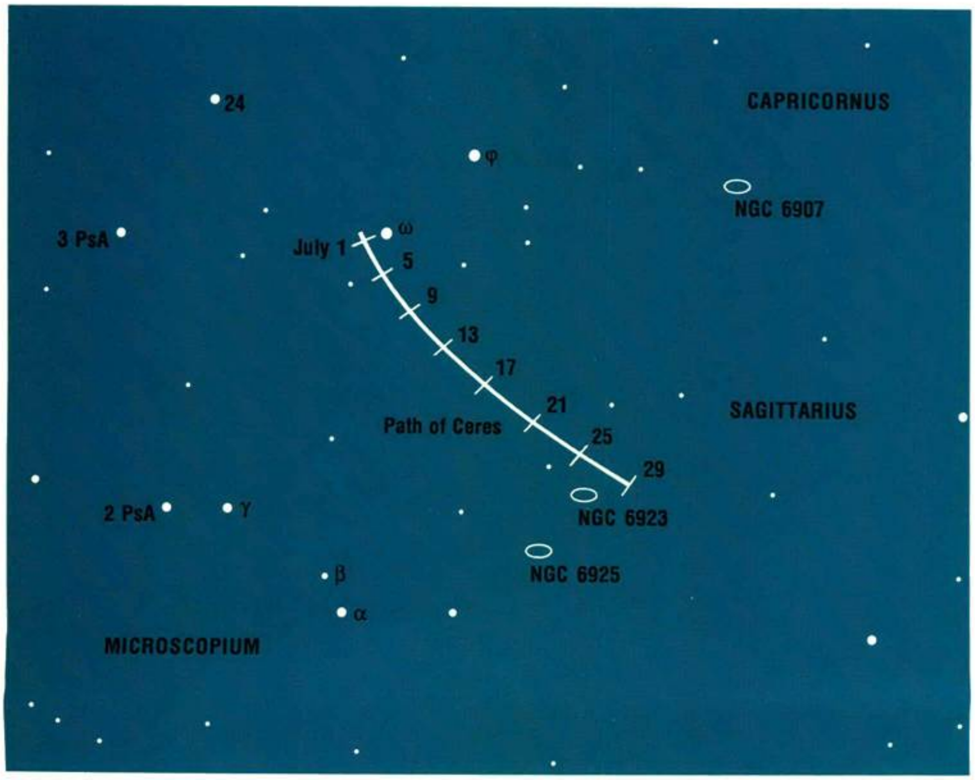
Speaking of occultations, the Moon also occults Theta Ophiuchi just after midnight on the night of July 11/12 for observers in the central United States, and just before midnight July 11 in the western part of the country. Theta lies above Scorpius' stinger in the southern half of the sky. This means the event will occur at a rather low altitude — as low as 10° in Denver to as high as 22° in San Diego — so be sure you have a clear southern horizon.

Although the occultation occurs two days before Full Moon, Theta is bright enough (magnitude 3.4) to withstand the glare. The occultation begins around 5h40m UT.

COORDINATES FOR CERES

Date	R.A. (2000.0)	Dec.
July 1	20h53.8m	–27°27'
July 5	20h51.2m	–27°54'
July 9	20h48.5m	–28°20'
July 13	20h45.4m	–28°46'
July 17	20h42.1m	–29°12'
July 21	20h38.5m	–29°37'
July 25	20h34.9m	–30°00'
July 29	20h31.2m	–30°21'

KING OF THE ASTEROIDS, Ceres comes to opposition on July 25. It is visible as a faint "star" in binoculars and telescopes. Track it by sketching the field and identifying the speck that moves relative to the background stars. The one that moves is Ceres.



TELESCOPIC PLANETS

The ringed planet **Saturn** just keeps getting better as the year progresses. Though opposition occurs next month (August 7), Saturn is now high in the southeast around 10:00 p.m. and is slowly growing brighter. At the beginning of July, it shines at magnitude 0.5 but increases to 0.3 by the end of the month. Additionally, Saturn, which has been at a low declination since 1987 (around –19°), is now edging ever northward, making it better placed for observers at northern latitudes. In July it is around –16.5°; by opposition it will be about –17°.

Right now, Saturn's disk has an apparent diameter of about 18". This grows to nearly 19" by opposition. The rings span 42", which is almost as wide as Jupiter's apparent equatorial diameter at opposition! During July, the north face of the rings are inclined about 15° toward Earth.

Now is a good time to look for the Cassini division, which divides the outer A ring from the brighter B ring. This narrow, dark gap is fairly obvious against the brilliant rings, even under average seeing conditions. More elusive is the Encke division, which divides the A ring almost in half. Unlike Cassini's division, this feature is difficult to discern even in large telescopes under good seeing conditions, and the declining inclination of the rings doesn't help matters. Use the most magnification that seeing will allow and be patient; wait for windows of steady air to pass between you and the planet. Keep an eye on the ansae, the extreme outer curve of the rings as seen from Earth. It is there that you'll be more likely to see the gray, hairline Encke division running through the A ring.

Jupiter and **Mercury** dominate the western sky after sunset this month. Though they approach each other, they never get closer than 23°. On the 2nd, though, the three-day-old Moon slides past them. A beautiful composition!

Jupiter is still in Leo and has been for the past year, bumping along beneath the belly of the Lion. Next month, though, Jupiter will be harder to see as it sinks nearer the Sun's glare and solar conjunction in mid-September. This may be your last opportunity to get a good view of Jupiter in the evening sky this year.

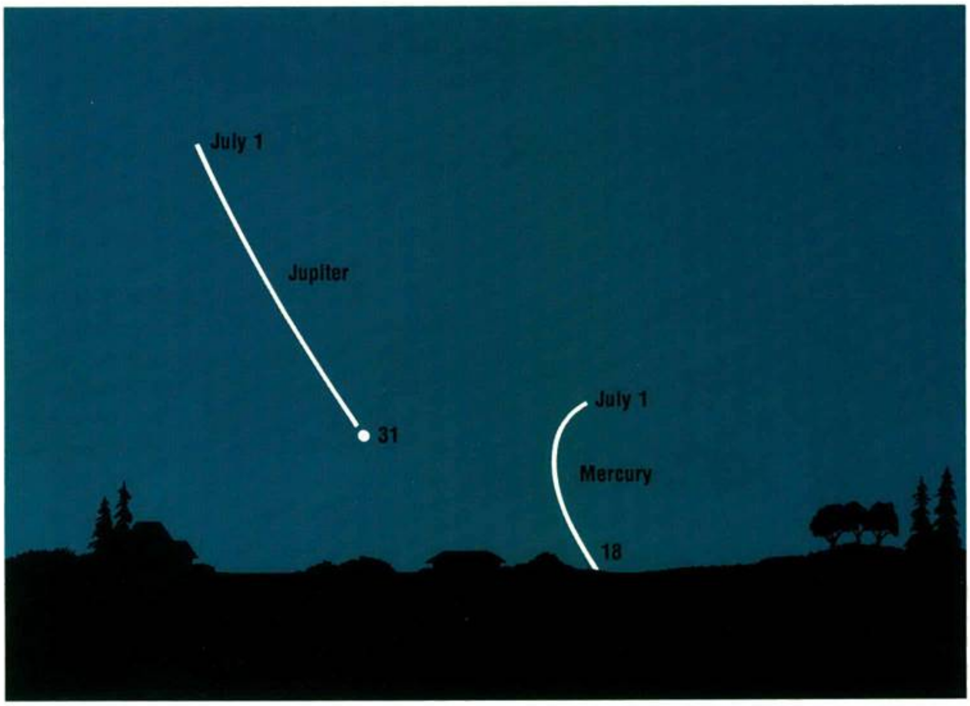
Aim your telescope at Jupiter as soon as possible after sunset while it's still fairly high above the horizon. Use moderate to high magnification. In a still-bright twilight sky, Jupiter's reflective glare is noticeably suppressed, allowing a flat view of subtle cloud features on the disk. Look for blue festoons extending from the North Equatorial Belt toward the equator and mottling in the clouds of the North and South Temperate Zones. Also note the color of the Red Spot. Judging from the observer reports I've heard recently as well as the descriptions on various computer bulletin boards, activity in both the North and South Equatorial Belts is still quite high, so these also bear watching. It will be interesting to see if there are any changes in the planet's appearance after it reappears again in the morning sky in October.

Mercury, meanwhile, reaches greatest elongation on July 6 when it will be at its greatest angular extent from the Sun. For those at southerly latitudes 35° and less Mercury will be visible some 22° above the horizon around 9 p.m. local daylight time. Those at more northerly latitudes will need to look at an altitude of about 15°. Although this is not as favorable an elongation as the one last March, you will still want to try to observe Mercury. Use binoculars and look for an orange-hued "star" embedded in the twilight sky. Once you've found the planet, use your telescope for a closer look. In early July, the planet exhibits a quarter phase, like a tiny half-moon. By July 20, Mercury slims down to a crescent and appears slightly larger in apparent diameter.

ASTEROIDS IN THE EYEPIECE

With our largest minor planet **Ceres** now reaching aphelion, the opposition July 25 is not a favorable one as oppositions go. To make matters worse, Ceres is at a declination of –27° to –30° throughout the month and so is not well placed for those at northerly latitudes. Still, at magnitude 7.5, Ceres outshines all the other asteroids save Vesta, which, incidentally, put on a fine show at opposition last March.

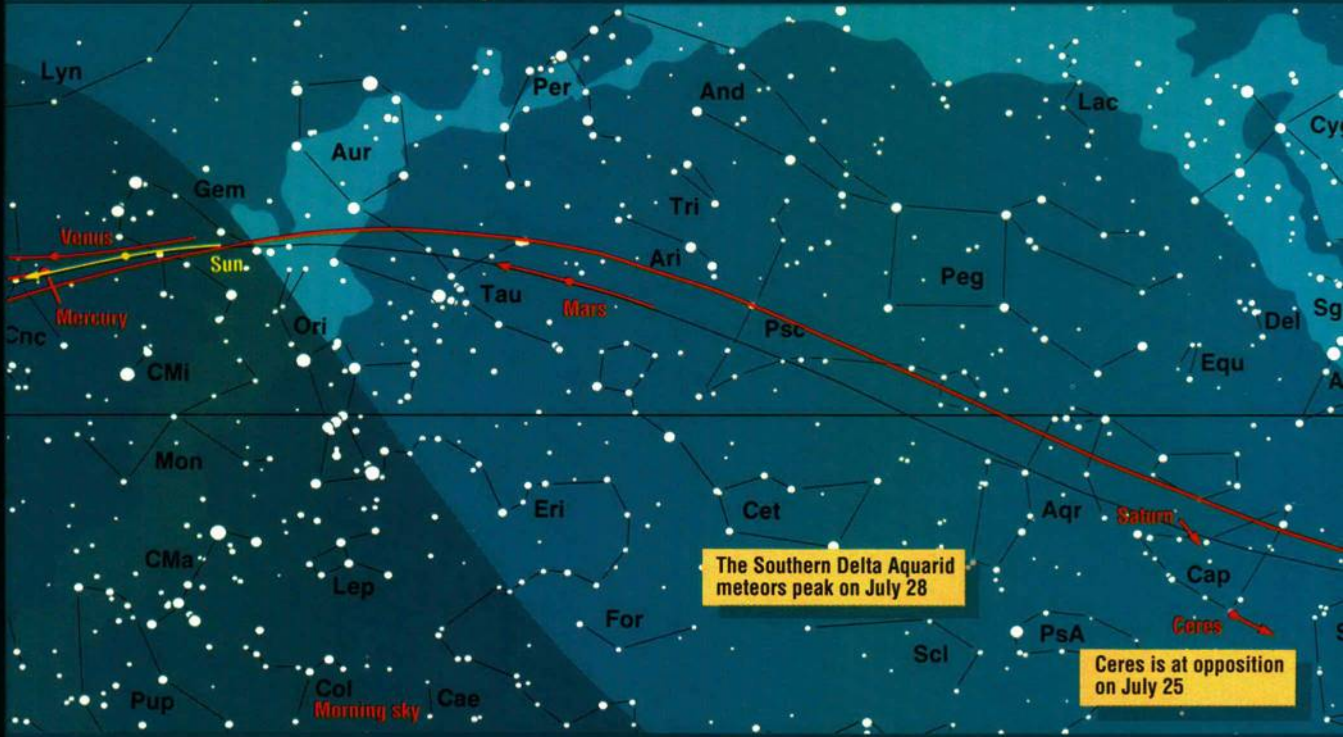
If you look for Ceres, you'll find it among the stars of Microscopium, which lies southeast of Sagittarius. Observers with setting circles can easily find this area by centering 3rd-magnitude Zeta Sagittarii — a star in the handle of the teacup — in the field of view and slewing eastward about one and a half hours in right ascension along declination –30°. If you don't have setting circles, grab your binoculars and look for a tiny cross of stars in eastern Sagittarius made up of Omega, 59, 60, and 62 Sagittarii. Your target region is about 5° southeast of this cross. Unfortunately, several 7th-magnitude stars in the area masquerade as asteroids. To pinpoint Ceres, sketch the field of stars and come back a night or two later to see which one moved. □



MERCURY AND JUPITER team up in the evening sky during the first days of July. Spot orange-hued Mercury with binoculars and then see if its crescent-shaped disk is visible in telescopes.

A former associate editor of ASTRONOMY, Jeff Kanipe is the editor of Star Date *magazine, which is published by McDonald Observatory at the University of Texas at Austin.*

The Solar System July 1992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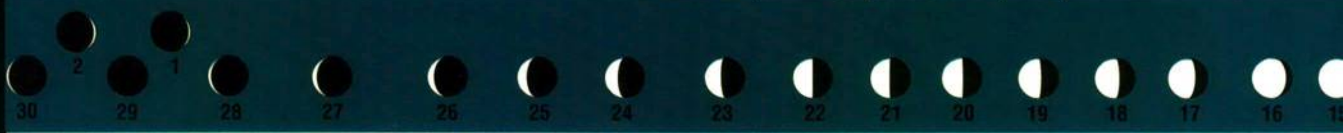
Morning sky

The Southern Delta Aquarid meteors peak on July 28

Ceres is at opposition on July 25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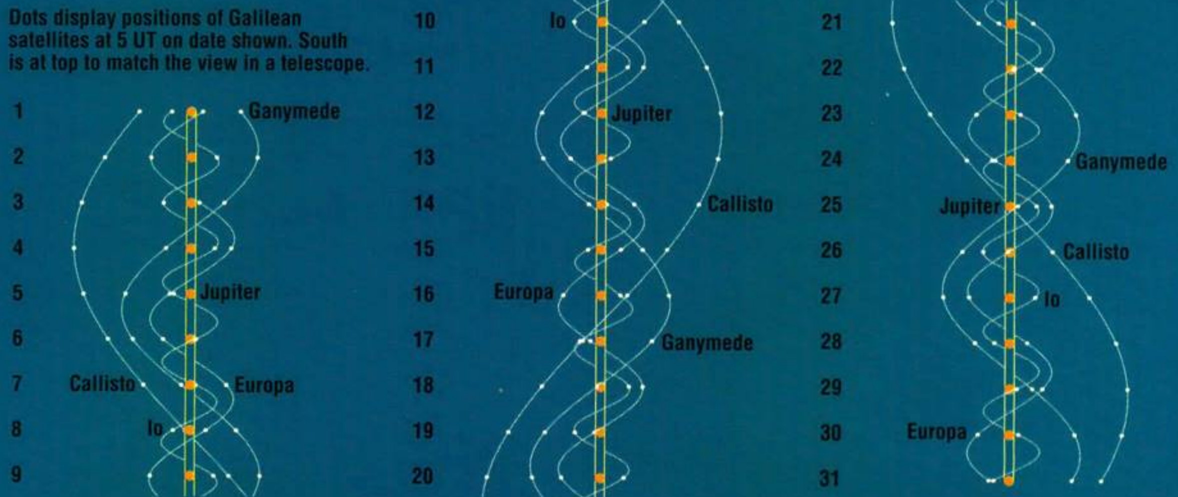
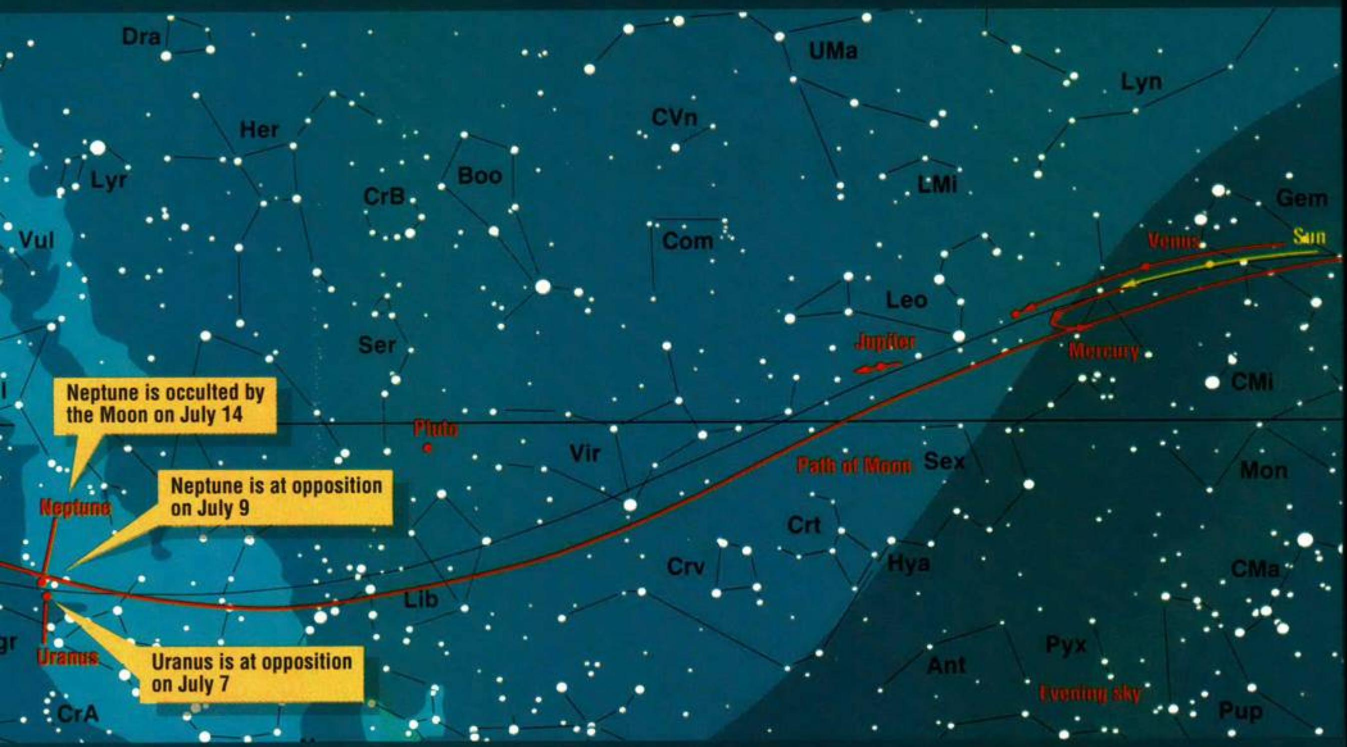
Planet	MERCURY	MERCURY	VENUS	MARS
Date	July 1	July 15	July 15	July 15
Magnitude	0.3	1.2	-3.9	0.8
Angular Size	7.3"	9.5"	9.8"	5.9"
Illumination	50%	26%	99%	89%
Distance (AU) from Earth	0.917	0.707	1.707	1.583
Distance (AU) from Sun	0.437	0.467	0.718	1.405
Right Ascension (2000.0)	8h30.0m	9h13.5m	8h16.0m	3h19.2m
Declination (2000.0)	+19°46'	+13°52'	+21°00'	+17°18'

Jupiter's Moons

Dots display positions of Galilean satellites at 5 UT on date shown. South is at top to match the view in a telescope.

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Venus
Sun
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Jupiter
Mercury
CMi
Neptune is occulted by the Moon on July 14
Pluto
Vir
Path of Moon
Sex
Mon
Neptune is at opposition on July 9
Neptune
Crt
Crv
Hya
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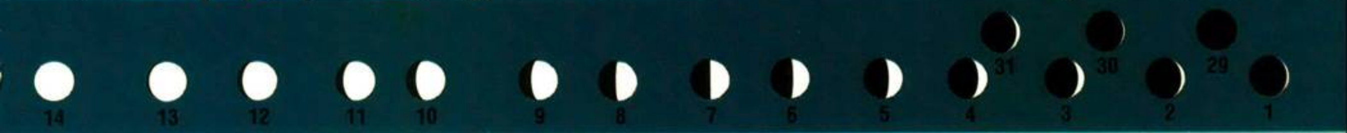
Uranus
Uranus is at opposition on July 7
Pyx
Ant
CrA
Evening sky
Pup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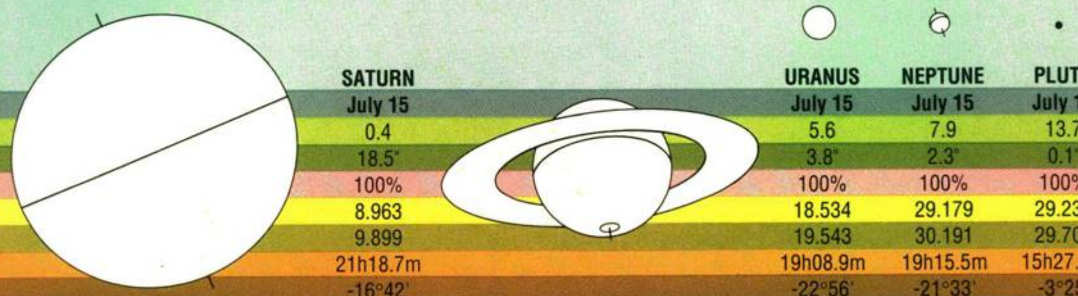
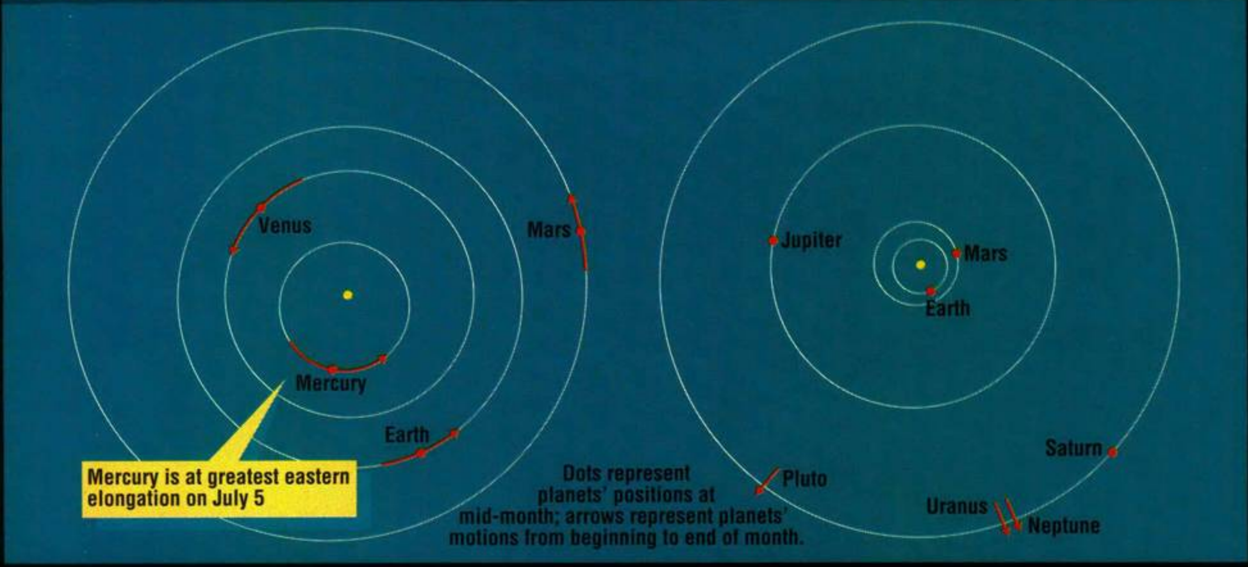


JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
July 15	July 15	July 15	July 15	July 15
-1.8	0.4	5.6	7.9	13.7
33.6"	18.5"	3.8"	2.3"	0.1"
99%	100%	100%	100%	100%
6.036	8.963	18.534	29.179	29.237
5.428	9.899	19.543	30.191	29.703
10h55.8m	21h18.7m	19h08.9m	19h15.5m	15h27.2m
+8°02'	-16°42'	-22°56'	-21°33'	-3°25'

The Planets in Their Orbits


Venus
Mars
Mercury
Earth
Jupiter
Mars
Earth
Saturn
Pluto
Uranus
Neptune

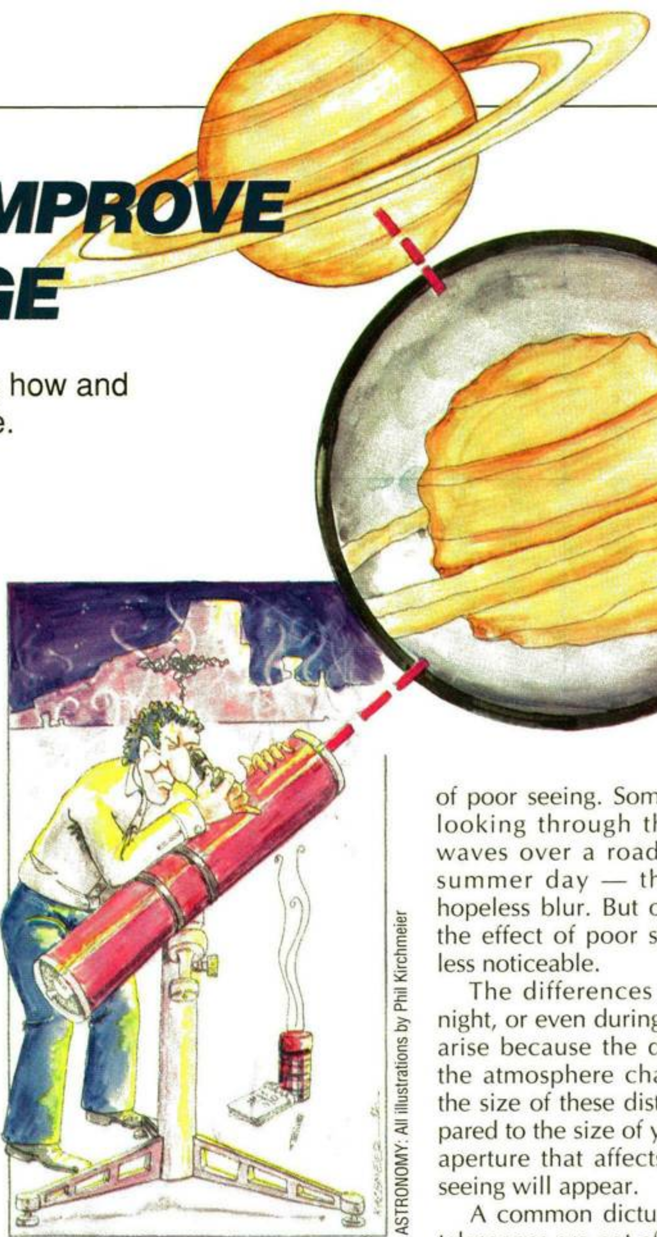
Mercury is at greatest eastern elongation on July 5

Dots represent planets' positions at mid-month; arrows represent planets' motions from beginning to end of month.

HOW TO IMPROVE YOUR IMAGE

Cure fuzzy images by learning how and where to set up your telescope.

By Rod Pommier



ASTRONOMY: All illustrations by Phil Kirchmeier

It's a clear night, the first after a long spell of cloudy weather. You're eager to finally get an evening's use of your telescope. Saturn is well placed in the sky and you're looking forward to a great view.

But wait. Instead of crisp images, you see a featureless blur. Has something gone wrong with your telescope? No. Chances are the culprit isn't your optics but turbulence in the atmosphere. Even when the weather cooperates with cloudless skies, you may find yourself faced with what's known as "poor seeing conditions."

You might think that poor seeing would be like the weather itself — one of those things that everybody complains about but nobody can do anything about.

But this isn't entirely true. You can take several steps to minimize the blurring effects of turbulence so you can get the most out of those much-anticipated clear nights.

Looking Sharp

Ideally, a telescope's optics take parallel light rays from the sky and bring them to a common focus. In practice, the parallel rays travel through a long column of air within Earth's atmosphere before reaching the telescope. Air, like the glass in a lens, bends light, and the column of air in front of a telescope is as much a part of your optical system as any lens or mirror in the telescope.

Air bends light differently depending upon its density which, in turn, depends on the air's temperature. If a column of air has the same temperature all along its length, then the image formed by the telescope will look sharp and steady. Under these ideal conditions, you'd get the sharpest possible view.

But on most nights, the air column is riddled with layers of varying temperature. In this case, each layer acts as a lens with a different refractive index — each bends the incoming light slightly differently. This causes light rays making up an image to arrive at the telescope via different pathways and to arrive at slightly different spots in the eyepiece. The result is a less-than-perfect image — the disk of a planet will look maddeningly out of focus. Perhaps it will waver or move around. Only occasionally will it snap into focus. Stars will look like bloated, squirming fuzzballs, not crisp points. Close double stars will merge into elongated blurs.

Unfortunately, viewing on most nights is hampered by some degree of poor seeing. Sometimes it's like looking through the rising heat waves over a road during a hot summer day — the image is a hopeless blur. But on most nights, the effect of poor seeing is much less noticeable.

The differences from night to night, or even during a single night, arise because the disturbances in the atmosphere change size. It is the size of these disturbances compared to the size of your telescope's aperture that affects how bad the seeing will appear.

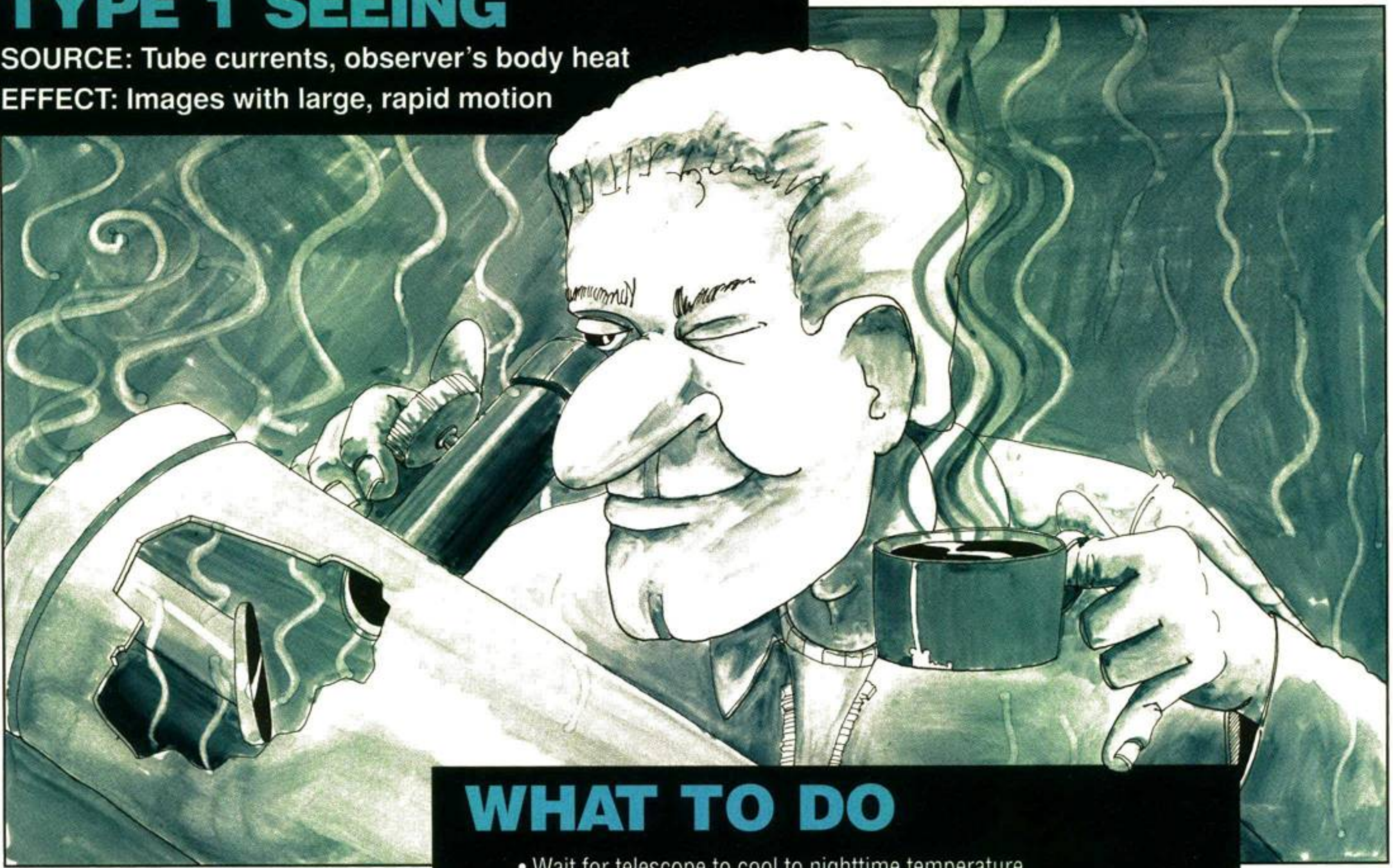
A common dictum is that small telescopes are not affected as much by poor seeing. For example, set two telescopes side by side, a 4-inch and a 16-inch, and aim both at Saturn. The 4-inch telescope takes in a 4-inch-wide column of air, the 16-inch scope a column four times wider. If the waves of disturbed air are about 4 inches across (as is typical on many nights), Saturn will look satisfyingly sharp in the 4-inch scope — the air within the column is relatively stable. But the entire air column is moving back and forth as a whole. As a result, the image in the 4-inch wobbles around the field.

Now look through the 16-inch scope. Its large aperture is looking through several waves at once. Saturn now stays put, but looks blurry and is beset with ripples washing over its disk.

At first glance the image in the 4-inch looks sharper. It doesn't seem to be wavering in and out of

TYPE 1 SEEING

SOURCE: Tube currents, observer's body heat
EFFECT: Images with large, rapid motion



WHAT TO DO

- Wait for telescope to cool to nighttime temperature
- Keep downwind of telescope aperture
- Avoid touching telescope tube
- Avoid walking in front of telescope

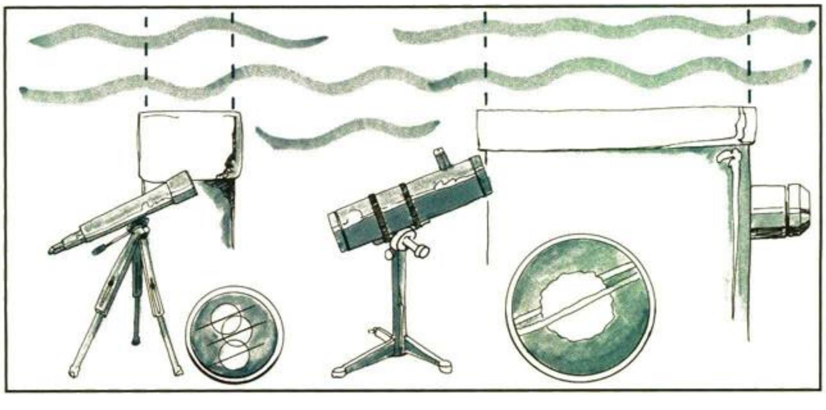
focus as much. But watch carefully through the 16-inch scope. Occasionally, Saturn settles down. If conditions are average, this won't happen often. But when it does, it will be like lifting a veil from the image. The 16-inch scope will definitely show more detail than the 4-inch, but only during fleeting moments of good seeing.

Because they look through wider columns of air, large telescopes, more often than small, are affected by poor seeing. It takes an exceptionally steady night for a large-aperture telescope to perform at its best. However, no matter what size telescope you own you still have to contend with turbulence in the air. After a while you realize that poor seeing takes different forms. For practical purposes, we can divide seeing conditions into three major types.

Keeping Your Cool: Type 1 Seeing

During what I call Type 1 seeing, images undergo rapid changes. The limb of an extended object, such as the Moon or a planet, appears to shimmer. The edge of the Moon or a planet splits into two or more separate limbs and the image oscillates rapidly from one limb to another. Point sources, such as stars, occasionally appear double or even triple. The image of an out-of-focus star appears granular or boiling. You might be able to catch glimpses of fine details on the Moon or a planet, but for the most part, the details appear to be oscillating so rapidly that you can't get a good look.

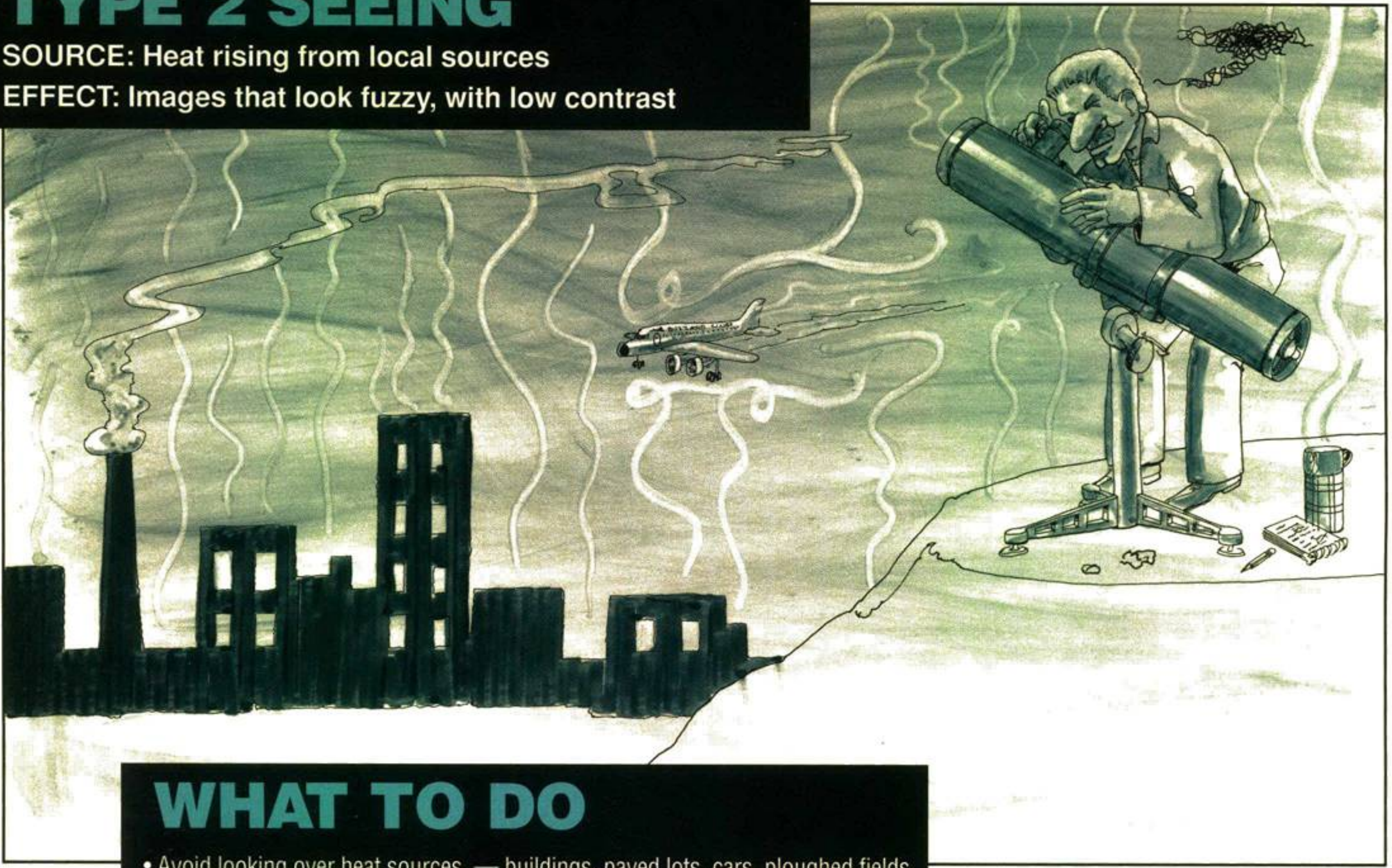
The causes of Type 1 seeing are air currents with very small sizes relative to the telescope aperture (approximately one-tenth to one-fourth the aperture of the telescope). The disturbing waves are often within the telescope tube itself or very close to the telescope. These small waves effectively divide the telescope into a number of smaller apertures which are in constant motion with



A LARGE SCOPE intercepts more waves of turbulence. When the seeing is poor, a small scope may give an image that looks sharper but moves around.

TYPE 2 SEEING

SOURCE: Heat rising from local sources
EFFECT: Images that look fuzzy, with low contrast



WHAT TO DO

- Avoid looking over heat sources — buildings, paved lots, cars, ploughed fields
- Avoid sites prone to night breezes — mountain valleys, shorelines
- Wait until late at night when ground has cooled off
- Stop-down the telescope aperture

respect to each other. This explains the multiple images.

The sources of Type 1 disturbances include a telescope tube and optics not cooled down to the night air temperature, heat waves conducted from your body to the telescope tube, heat waves from people near the telescope, and heated dew caps.

To eliminate this type of seeing, always allow at least 30 minutes for the telescope tube to reach ambient temperature. (Cool-down can take an hour or more if the night is cold or the telescope is large.) If you have a reflector with an open tube that you normally cover with a cloth light shield, then leave the cover off for the first 30 minutes or so.

Once the telescope tube has cooled down, avoid it. Move the telescope tube by grabbing the mount or tube handles instead.

To keep heat waves from wafting in front of the telescope, stand downwind from the tube as much as possible. Don't walk or stand in front of your telescope. When observing in a group, allow plenty of space between you and other observers.

Further Afield: Type 2 Seeing

With Type 2 seeing, images don't move as rapidly as they do under Type 1 conditions but are decidedly blurred. The limbs of lunar and planetary disks appear single but indistinct — planets appear surrounded by a glow. Fine details on lunar or planetary disks are invisible. Overall contrast is diminished. Star images are not pinpoints but spread out. Out-of-focus images of stars show colorful twinkling.

Type 2 air currents have sizes that are typically one-half your telescope's aperture. The effect of waves of this size is to impart different focal lengths to different parts of your mirror or lens. This creates a situation that mimics spherical aberration, an optical flaw in which the main mirror or lens has no precise focal point.

Type 2 seeing originates in the lower atmosphere, often from heat waves rising from the ground and from nearby buildings. Different materials radiate heat at different rates. Concrete and buildings radiate heat more rapidly than grass does. Land radiates heat more rapidly than water. If you are looking over an area where two dissimilar terrains meet, you'll be looking through air of different temperatures and densities.

At night, for example, cool air from a mountain top will turbulently tumble down the mountainside into a valley, creating cool mountain breezes and poor seeing conditions.

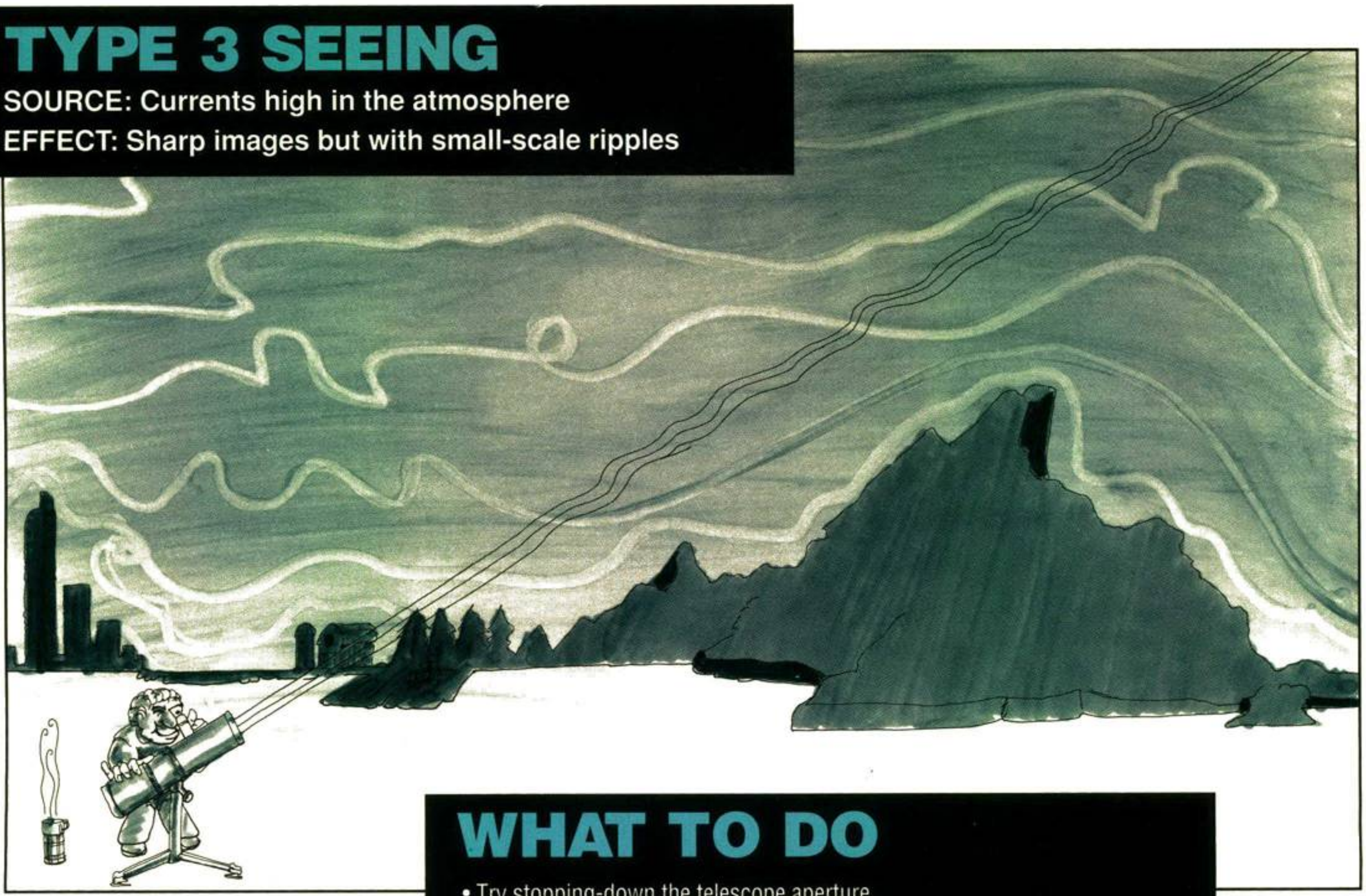
A similar situation occurs near bodies of water. Shortly after sunset, the land will be cooler than the water. As warm air continues to rise over the water, cool air from the land rushes in to replace it, giving rise to sea breezes.

After a cold front passes and skies clear, Type 2 seeing can occur over a large area. In this case, everything on the ground is warmer than the new colder air mass above — the ground radiates heat into the air, causing a widespread Type 2 disturbance.

The best remedy for Type 2 seeing is to move your telescope to a better location. Avoid areas overlooking heated buildings, parking

TYPE 3 SEEING

SOURCE: Currents high in the atmosphere
EFFECT: Sharp images but with small-scale ripples



WHAT TO DO

- Try stopping-down the telescope aperture
- Have patience — wait for moments of good seeing
- If night is really bad, pack it in and read ASTRONOMY!

lots, or large expanses of heat-retaining concrete. Select a location well inland rather than near a beach, lake shore, or river. Open areas within flat grassy fields are good locations. An observing site on top of a broad hill or mountain plateau is often better than one in a valley or on a downslope.

If you can't move, you can always wait. Most cooling of the surroundings is completed by midnight or 1:00 a.m. Because of this, lunar and planetary photographers often get their best photos in the early hours of the morning.

If you own a 10-inch or larger scope, try stopping-down your telescope's aperture. (Use a mask with a 4- to 6-inch hole in it.) Although your telescope will perform like a smaller scope, you may get a sharper image. The benefits of improved seeing sometimes outweigh the loss of resolution from the reduced aperture.

Looking Up: Type 3 Seeing

With Type 3 seeing, images look fairly sharp most of the time but are subject to fast ripples. The limb of the Moon or a planet looks single but wavers noticeably. You can see fine lunar or planetary details but they shift slightly in position from moment to moment. Star images are crisp but are also in slight motion. They appear to dance in small circles or patterns.

The cause of Type 3 seeing lies in the upper atmosphere, far above the telescope. These disturbances have wavelengths that are very large relative to your telescope's aperture, often three or more times larger. Their effect is to distort the image and its position slightly, much as waves on the surface of a swimming pool or pond distort the apparent position of something in the water. If you get the impression that you are viewing through rippling water, then you are probably dealing with Type 3 seeing.

Because its source lies far away, there's not much you can do to improve this type of seeing. Stopping-down your telescope is worth a try. In this case, however, the loss of resolution from the smaller aperture usually outweighs the small improvement in seeing.

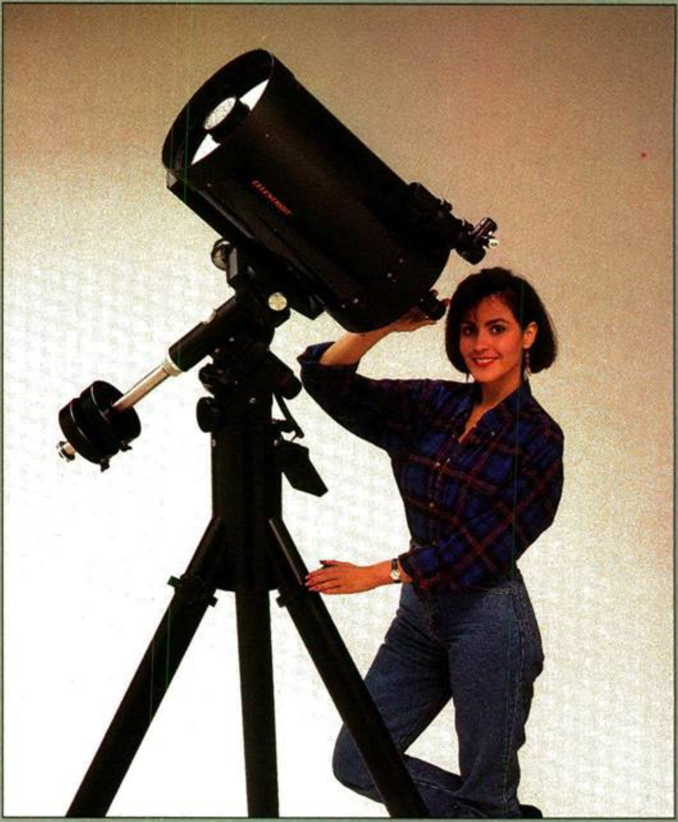
There really is nothing you can do about Type 3 seeing (as there is little you can do about the weather). But happily, its effects are usually mild. A Type 3 night is still a good night for viewing.

Of course, dividing up atmospheric seeing into three neat types is an ideal situation. In reality, the three kinds of poor seeing often occur in combination. On those nights, your eyepiece will present a confusing picture. Still, if you take care to correct the sources of Type 1 and Type 2 disturbances, you should see a noticeable improvement in the view through your telescope. Getting around the sources of bad seeing that are beyond your control simply takes the patience to wait for nights and moments of steady air. On those happy occasions, you'll be rewarded with as fine a view of the Moon, planets, and stars as your telescope is capable of. □

Rod Pommier is a surgeon at the Oregon Health Sciences University in Portland and has been an amateur astronomer since age 12.

INTRODUCING A NEW CELE

THE CG-11 - A C11 REVOLUTION



Celestron Innovation... The new CG-11 combines the unequalled optical excellence of the current C11 with a superb new mount design.

The impressive mount is built for Celestron by Losmandy, a highly respected U.S. manufacturer. Five years of experience with this mount have brought about a mount with twice the rigidity at half the weight. The end product is SOLID with a dampening time so fast as to be almost unmeasurable. Legendary Losmandy tracking precision can now be yours in this affordable package.

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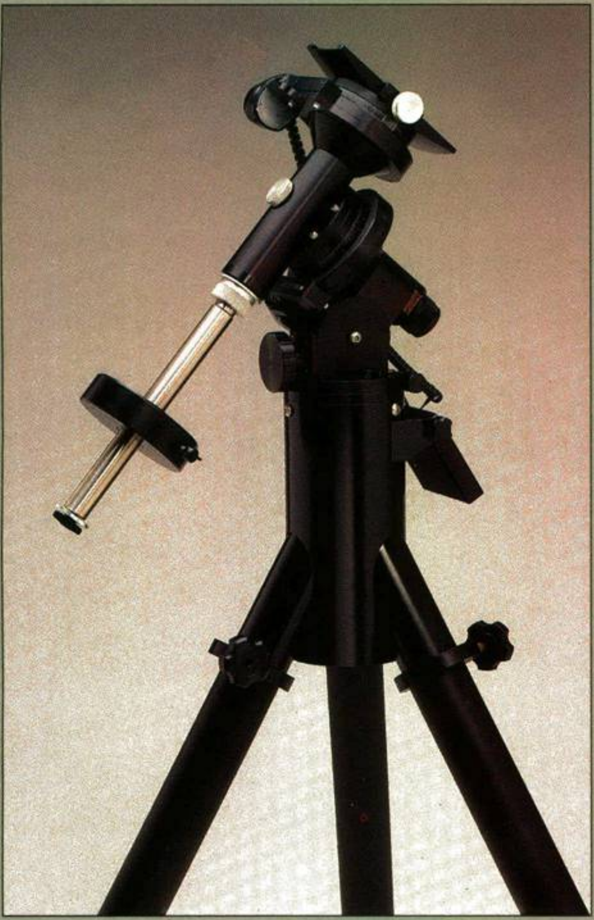

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Above: Mount with Astro-Physics refractor

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Exploring the Wonders of Scutum

Star clusters and nebulae highlight the richly studded area of the Milky Way known as the Scutum star cloud.

by Robert Garfinkle

The Summer Milky Way contains the small constellation originally known as *Scutum Sobiescianum* (Sobieski's Shield, after the coat of arms of John Sobieski III, king of Poland). On most modern star atlases and constellation listings the 84th constellation in size — the smallest with four exceptions — is known simply as Scutum.

Though small, Scutum's 109 square degrees of sky are packed with millions of stars, as this area is situated along the plane of our Galaxy and is visually near the Galaxy's core. Scutum contains many double and multiple systems, variables, dark and emission nebulae, star clusters, planetary nebulae, and the famous Scutum star cloud. Scutum fits into a pocket formed by Sagittarius the Archer to its south and southeast, Aquila the Eagle to the east and north, and Serpens the Serpent to the west.

IC 1287

Mag. —

Size 44' by 34'

by Martin C. Germano

Let's start our tour of Scutum near the center of the constellation at the 3.9-magnitude, spectral class K3 III red giant **Alpha Scuti** (1 Aquilae). About 15' east of Alpha lies the largest open cluster in Scutum. The 50 members of **NGC 6664** are spread out and shine with an integrated magnitude of 7.8. The brightest members glow at about 10th magnitude. The cluster is about 4,250 light-years from the Sun.

On the eastern fringe of NGC 6664 lies the pulsating Delta Cephei-type variable, **Y Scuti**. This star's magnitude varies from 9.2 to 10.0 during a period of 10 days. In pulsating variables, the photosphere and outer layers of the star periodically expand and contract. These heartbeatlike pulsations cause the changes in the star's apparent brightness.

The Wild Duck Cluster (M11)

Mag. 5.8

Size 14'

by Bill Iburg

Another variable member of NGC 6664 is the short-period Delta Cephei-type star, **EV Scuti**. In contrast to regular Delta Cephei variables, the short-period ones have visual amplitudes of less than 0.05 magnitude and their periods are less than 7 days. Regular Delta Cepheids have amplitude ranges of 0.02 to 2.0 magnitudes and can have periods as long as 50 days.

Move about 30' southeast of NGC 6664 and you'll come to the small open cluster **Trumpler 34**. This cluster contains just 8 members and shines at magnitude 9.4. The short-period pulsating variable **Delta Scuti** (2 Aquilae) lies about 30' south-southeast of Trumpler 34. Delta Scuti is the prototype for short-period variables that show slight fluctuations in their brightness during a period of less than 5 hours. In the Delta Scuti class, this fluctuation is about 0.2 magnitude or less. Delta's magnitude fluctuates from 4.9 to 5.2. The changes in your own local seeing during the night can cause you to see this much difference in a

The Wild Duck Cluster (M11)

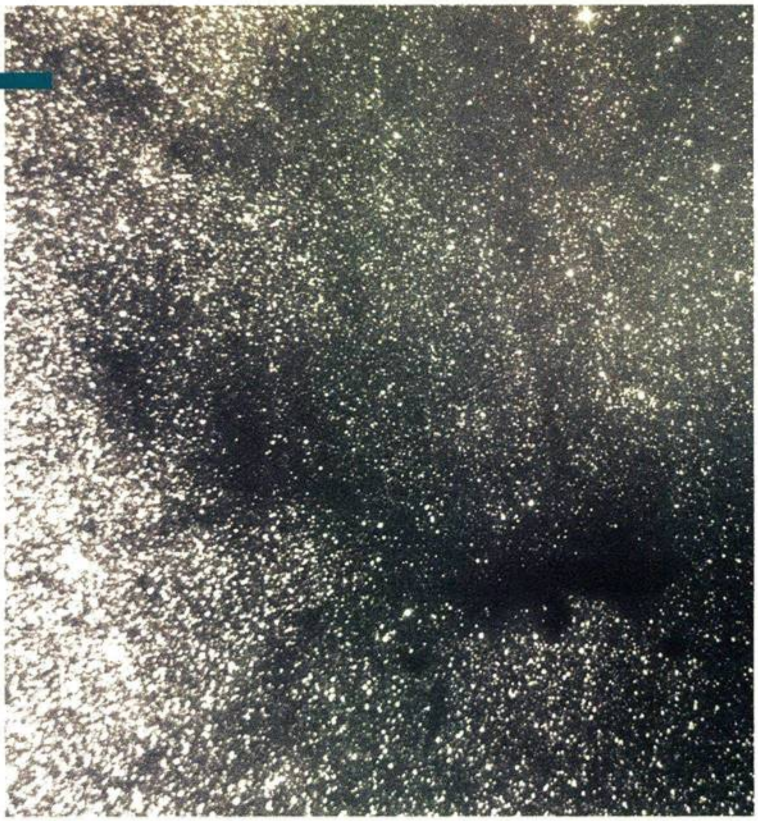
Mag. 5.8

Size 14'

by Kim Zussman

star's apparent magnitude, so you will have to compare Delta with the stars around it to see if they are also changing in brightness. If these other stars do not appear to dim or brighten while Delta is changing, then you are observing Delta during one of its pulsations.

Delta Scuti variables are all young stars and fit within spectral classes A5 to F5. Unlike many of the other types of variable stars, the spectral type for a Delta Scuti star remains constant during the star's pulsations. We know of about 100 Delta Scuti-type stars. Because these



Barnard 103

Mag. —

Size 40' by 40'

by Martin C. Germano

stars are Population I giants, they are all located in or near the Milky Way and generally are members of open clusters. Many of these stars appear to be short-period spectroscopic binary stars. This leads astronomers to think the rapid motion and gravitational effects of the nearby companion star may be a cause of the pulsations in the primary.

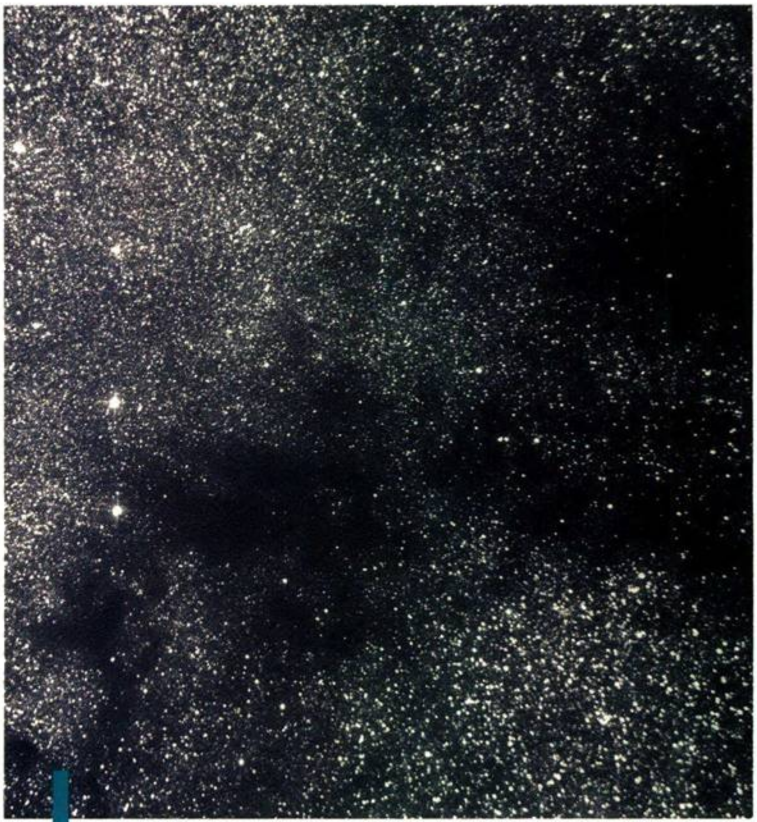
Delta Scuti has two visual companions. The magnitude 9.2 C star was first measured in 1879. This star lies 52" from the primary in position angle 130°. The fainter (magnitude 12.2) B star was first measured in 1938. This star can be found at position angle 46° and has a separation from the primary star of 15". The Delta Scuti system is about 250 light-years away and is moving at 29 miles per second toward us.

On the evening of June 20, 1764, French astronomer Charles Messier noticed a cluster of stars near Delta Scuti and added it as the 26th object on his list of cometlike objects. This open cluster is now designated as **M26** (NGC 6694) and looks like a wishbone or tuning fork pattern of stars with four bright stars near the center. Two curving arms of fainter stars fan out north and south of the cluster's center. M26 has a magnitude of 8.0 — its brightest member is a magnitude 11.9 bluish giant. The 100 stars that make up M26 are located about 4,900 light-years away.

After observing M26, star-hop about 2° east-northeast to the globular cluster **NGC 6712**. In small scopes, this magnitude 8.2 cluster appears somewhat nebulous with no individual stars visible. Larger instruments (13 inches or greater) can resolve individual stars around a very dense core. The cluster lies about 24,700 light-years away. Southeast of NGC 6712, in the same field of view, you'll find the magnitude 15.0 planetary nebula **IC 1295** (PK 25-4.2). When you view this object you'll see that two 13.5-magnitude stars appear to be surrounded by a thin shell of nebulosity. Compared to most planetary nebulae, IC 1295 is quite large — it measures 86" across. The object has a low surface brightness, so if you have a high contrast, red-transmissive nebula filter, use it. Once you have IC 1295 centered in a low-power eyepiece, switch to high power to get the best view of it.

The heart of the **Scutum star cloud** itself lies south of Delta Scuti. This gigantic concentration of faint stars is visible to the naked eye but shows best with binoculars. In some parts of the cloud, the stars are so densely packed you can hardly see black space between them. This is one area of the sky you should take your time to look over and savor.

On the western fringe of the Scutum cloud you'll find a triangle formed by the open cluster **NGC 6649**, the reflection nebula **IC 1287**, and a 5th-magnitude star. NGC 6649 contains about 50 members in a tight grouping located 4,250 light-years away. This 8.9-magnitude cluster appears to be the hub for several

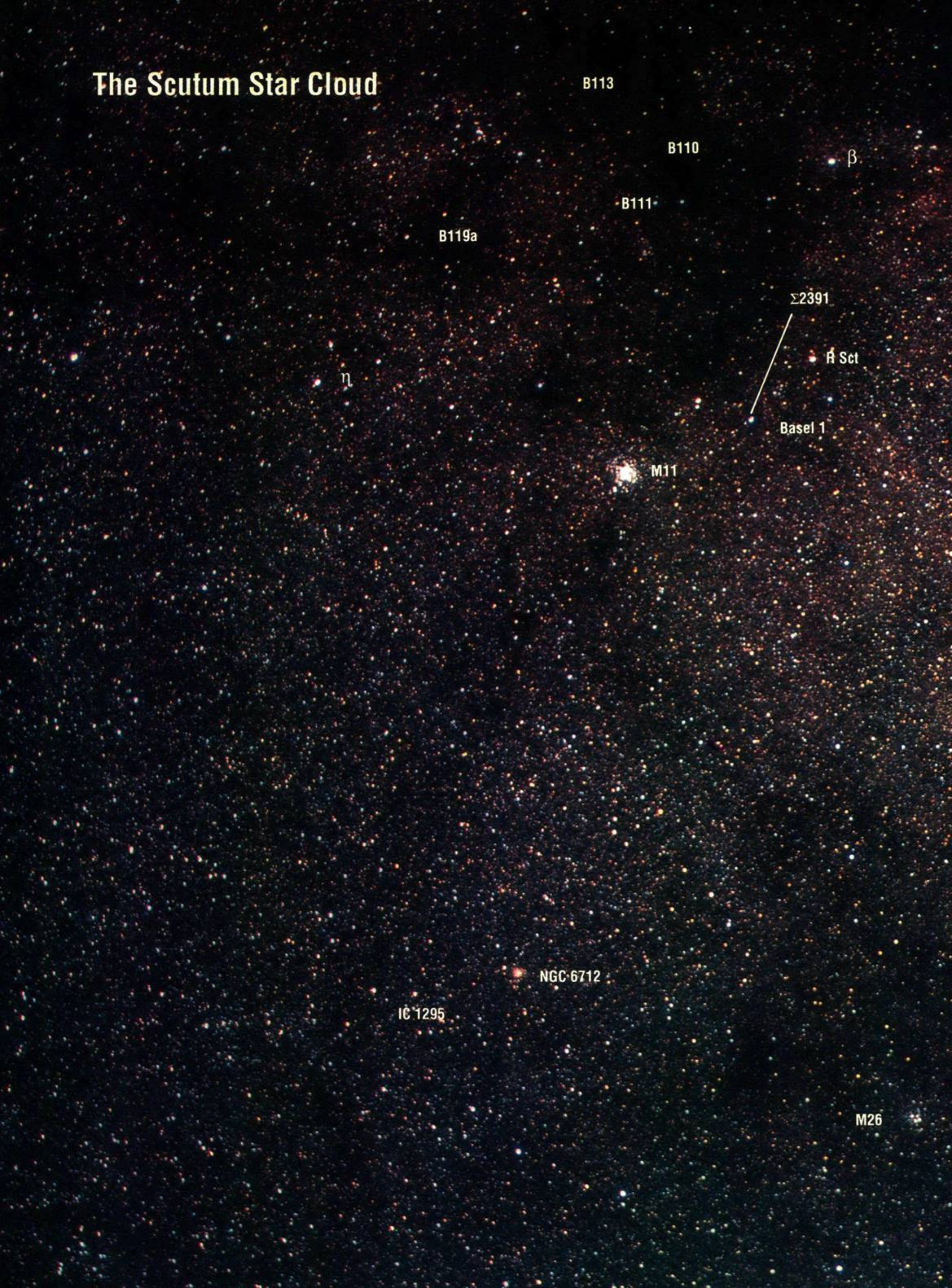


Barnard 111

Mag. —

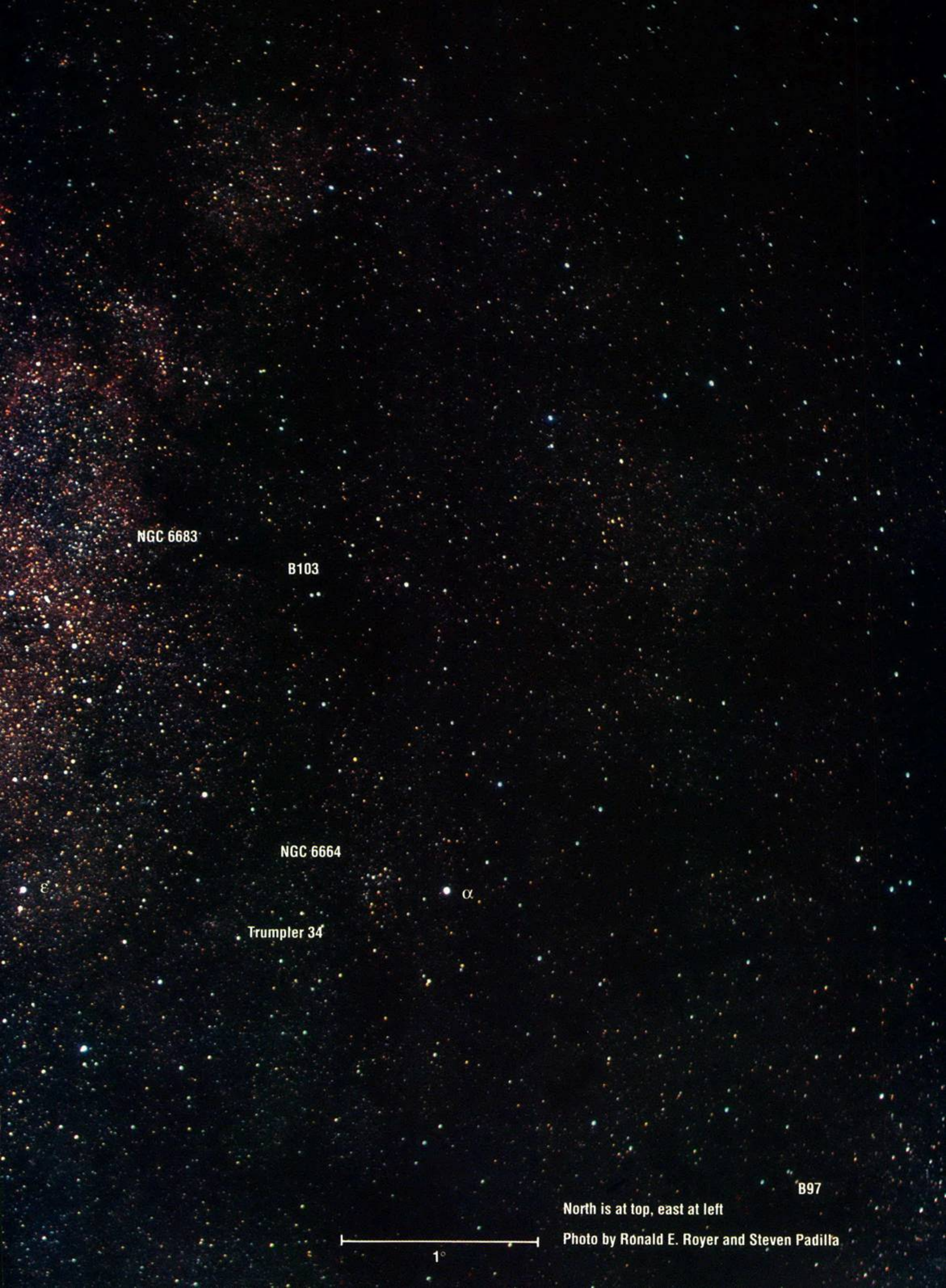
Size 120' by 120'

by Martin C. Germano



The Scutum Star Cloud

B113
B110
β
B111
B119a
Σ2391
R Sct
η
Basel 1
M11
NGC 6712
IC 1295
M26

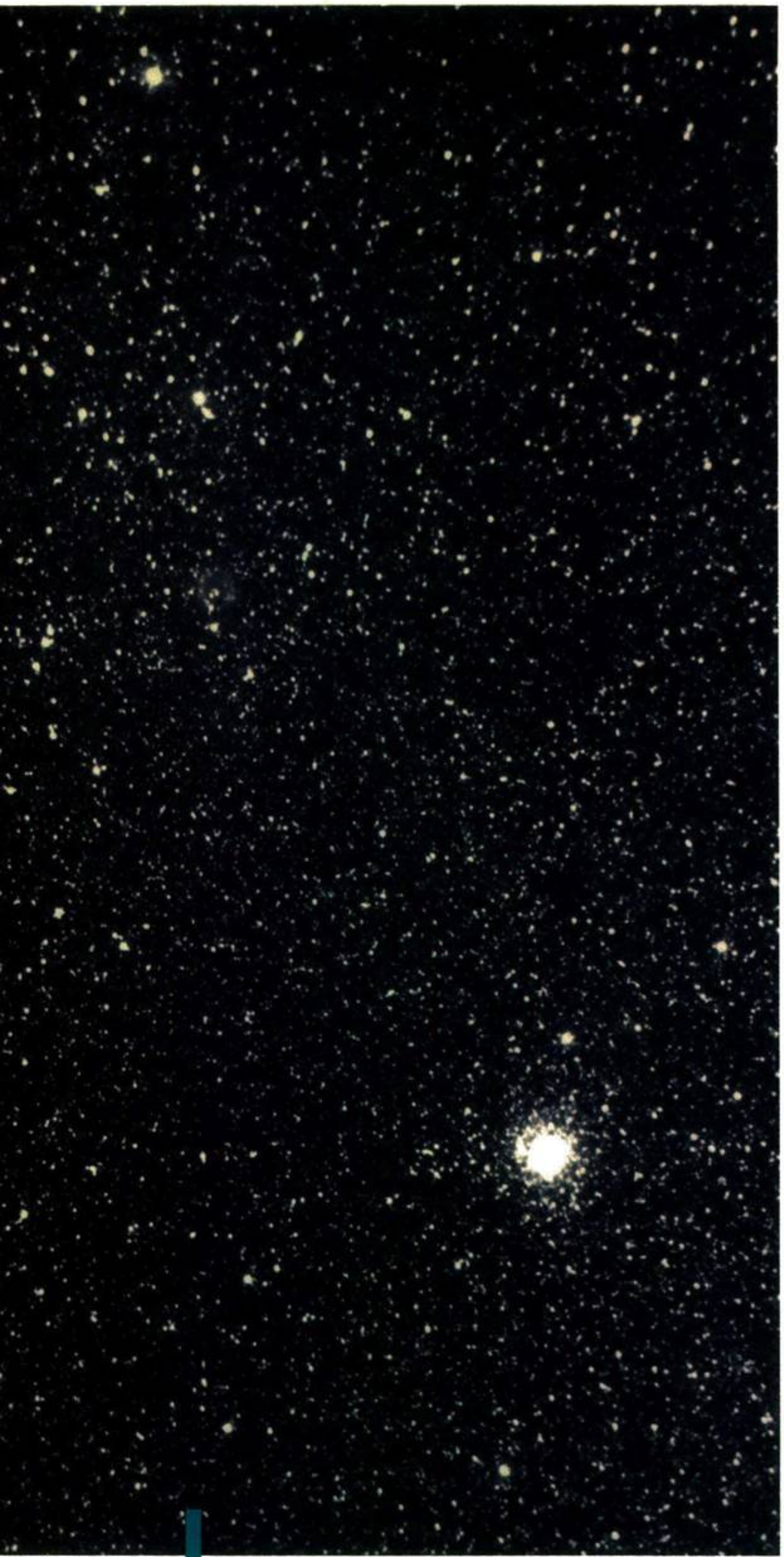

NGC 6683
B103
NGC 6664
ε
α
Trumpler 34
B97
1°

North is at top, east at left

Photo by Ronald E. Royer and Steven Padilla

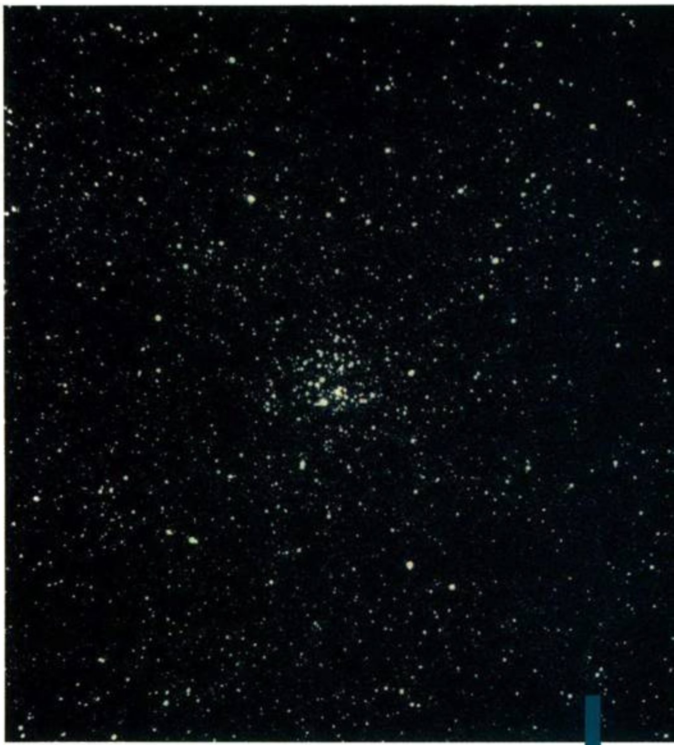
DEEP-SKY OBJECTS IN SCUTUM

OBJECT	R.A. (2000.0)	DEC.	MAG.	SIZE/SEP.
Dolidze 28	18h25.4m	-14°39'		12'
B97	18h29.1m	-09°56'		50' by 50'
Gamma Scuti	18h29.1m	-14°33'	4.7	
B312	18h30.9m	-15°08'		100' by 30'
IC 1287	18h31.3m	-10°50'		44' by 34'
Ruprecht 141	18h31.3m	-12°19'	12p	7'
Struve 2325	18h31.4m	-10°48'	5.8	12.3"
NGC 6649	18h33.5m	-10°24'	8.9	6'
Alpha Scuti	18h35.1m	-08°14'	3.9	
EV Scuti	18h36.7m	-08°13'	9.9,10.3	
Y Scuti	18h36.7m	-08°13'	9.2,10.0	
NGC 6664	18h36.7m	-08°13'	7.8	16'
B103	18h39.2m	-06°37'		40' by 40'
Trumpler 34	18h39.8m	-08°29'	9.4	8'
NGC 6683	18h42.2m	-06°17'	9.5p	11'
Delta Scuti	18h42.2m	-09°03'	4.9,5.2	
M26 (NGC 6694)	18h45.2m	-09°24'	8.0	15'
R Scuti	18h47.3m	-05°42'	4.4,8.4	
Basel 1	18h48.2m	-05°51'	8.9	9'
Struve 2391	18h48.7m	-06°00'	6.5	37.9"
B318	18h49.7m	-06°24'		90' by 2'
B110	18h50.2m	-04°46'		9'
B111	18h51.0m	-05°		120' by 120'
B119a	18h51.0m	-05°		120' by 120'
M11 (NGC 6705)	18h51.1m	-06°16'	5.8	14'
B113	18h51.4m	-04°19'		11'
NGC 6712	18h53.1m	-08°42'	8.2	7'
IC 1295	18h54.6m	-08°50'	15p	86"



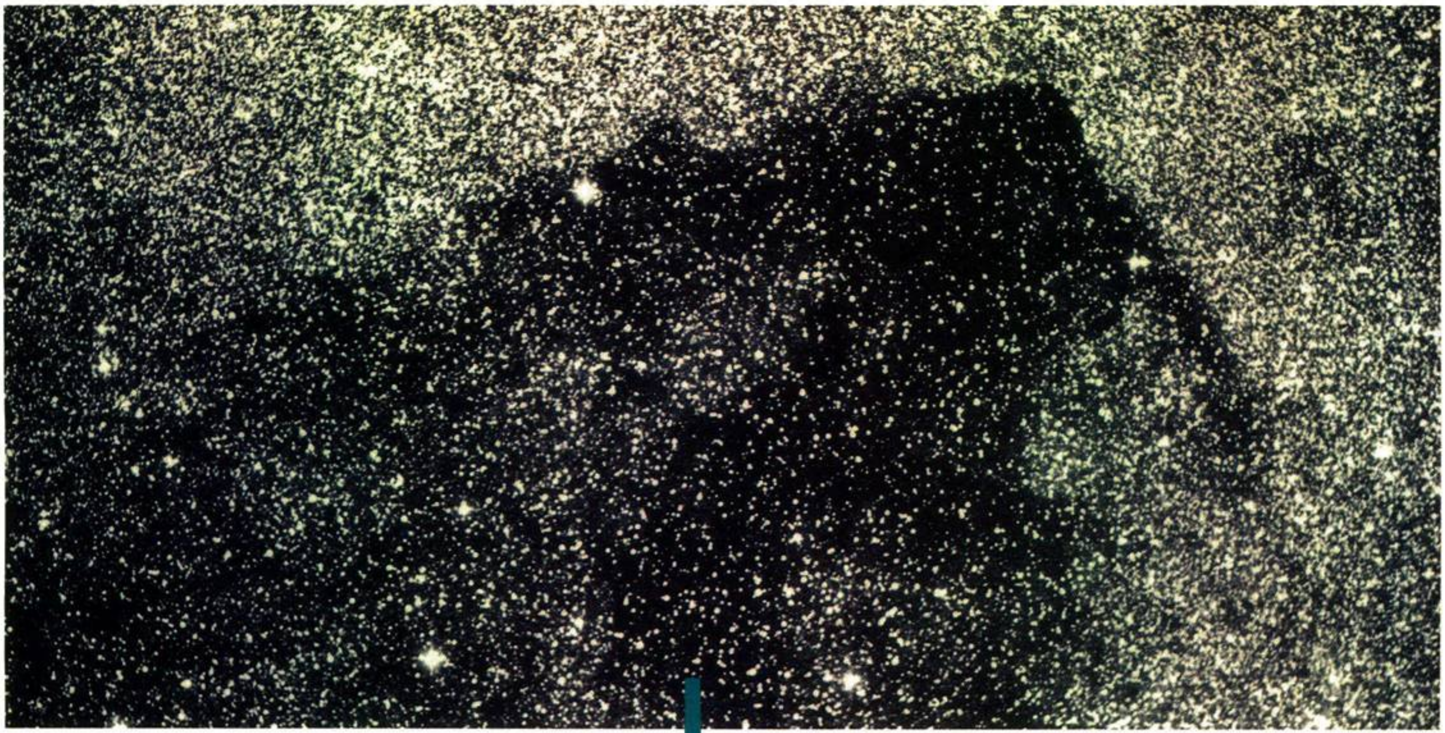
NGC 6712 and IC 1295

Mags. 8.2 and 15
Sizes 7' and 86"
by Martin C. Germano



M26

Mag. 8.0
Size 15'
by Lee C. Coombs



Barnard 312

Mag. —

Size 100' by 30'

by Martin C. Germano

spokes of dark dust lanes radiating throughout the surrounding starfield.

About 30' southwest of NGC 6649 you'll come to the reflection nebula IC 1287. Smack in the middle of the nebula lies the wide double star **Struve 2325**. A dust lane bisects the nebula southeast of the star. Struve 2325 consists of a 5.8-magnitude, spectral class B3, white primary and a 9.1-magnitude secondary located 12.3" away. Look for the secondary in p.a. 257°. F. G. W. Struve first measured this pair in 1829 when he served as director of the Dorpat Observatory in Estonia.

In the northern area of Scutum is the largest of the dark nebulae in Scutum, a complex consisting of **B110**, **B111**, **B113**, and **B119a**, and covering about three square degrees of sky. This dark nebula snakes its way through a rich star field. On the southern end of B111 is the bright open cluster M11 (NGC 6705), popularly known as the **Wild Duck Cluster**. While verifying the discoveries of his predecessors, Messier located this dense cluster on the night of May 30, 1764. German astronomer Gottfried Kirch discovered the cluster, however, more than sixty years earlier. About 600 stars brighter than magnitude 14.8 are visible in M11. The cluster contains hundreds of fainter stars and is rich in yellow and red giants. The stars are so tightly packed at the cluster's center that they may be less than one light-year apart. M11 is not part of the Scutum star cloud but is a foreground object. William Henry Smyth originated the Wild Duck nickname when in the mid-nineteenth century he recorded that phrase in an observing log. The thin black streak south of M11 is the dark nebula **B318**.

About 1° northwest of M11 you'll find the radially pulsating supergiant **R Scuti**. This star varies from magnitude 4.4 to 8.4 during a period of 140.5 days. The variability of this star was first noticed by the English astronomer Edward Piggot in 1775. R Scuti is in the class of variables whose prototype is RV Tauri. These variables appear to have two alternating minima. This causes the star to have various magnitudes at its extreme faintness phases. Most of the time, R Scuti is a 5th- or 6th-magnitude star. About every 146 days, the star fades to 8th magnitude and slowly rises back in brightness. R Scuti is a large star and may be as much as 100 times the diameter of the Sun.

Halfway between M11 and R Scuti is the multiple star **Struve 2391**. The primary is a 6.5-magnitude, spectral class A2 star. The 9.8-magnitude secondary lies 37.9" from the primary in p.a. 332°. This nice double is easy to split, even in small scopes. A third member of the system is a 14.3-magnitude star located 12" from the B star.

Sweep 1.5° west from M11 to the U-shaped open cluster **NGC 6683**. This cluster is hard to pick out from the edge of the Scutum star cloud. The 20 stars in the group have a magnitude of 9.5, with the brightest members glowing at 11th magnitude. The expansive dark cloud west of NGC 6683 is the dark nebula **B103**, which covers about one-half square degree of sky. The eastern portions seem darker than the western ones. In binoculars you can see twisting veins of dark matter throughout this complex.

Although Scutum is a relatively small star group, it offers something for everyone. It is a beautiful sight for naked-eye observers who gaze in awe of the Scutum star cloud. Binocular users will marvel at the Wild Duck Cluster. Telescope enthusiasts will enjoy scanning the constellation's rich star fields and winding lanes of dark nebulae. Scutum remains one of the great gems of the summer sky. ☐

Robert Garfinkle is the author of Star Hopping, *to be published later this year by Cambridge University Press.*

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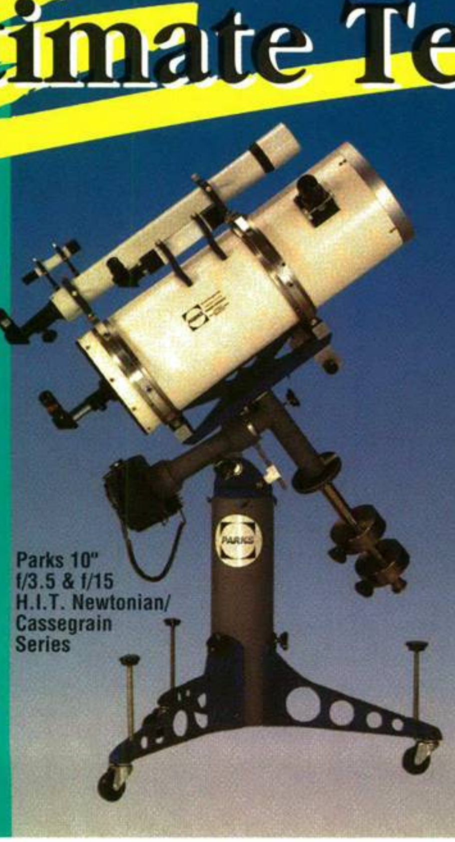

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Summer's Gift to Comet Observers

Catch Comet Shoemaker-Levy as it races across Earth's starry stage this summer.

by Richard Talcott

A small, faint smudge of light adorned the photographic plate. Using the 18-inch Schmidt telescope on Palomar Mountain, astronomers Eugene and Carolyn Shoemaker and David Levy were searching for Earth-crossing asteroids — small but potentially dangerous objects whose orbits intersect that of Earth. As they scanned a plate exposed on the morning of October 6, 1991, looking for the telltale motion of an Earth-crosser, they came across the smudge. Located in western Perseus, this was no ordinary smudge. It was the light from a comet no one had ever seen.

Named Comet Shoemaker-Levy after its discoverers, the comet spent most of the next eight months slowly looping through the constellation Andromeda. Now it is poised to make a mad dash across Earth's northern sky. During June and much of July, Comet Shoemaker-Levy shines brighter than 10th magnitude and lies far enough north that observers at mid-northern latitudes can watch it throughout the entire night. Then, in the second half of July, the comet shines at its brightest as it passes closest to the Sun. If the comet matches astronomers' predictions, it may then be bright enough to glimpse with the naked eye.

In the Dark of the Night

The key to getting a good view of the comet is to choose a good observing site. For Comet Shoemaker-Levy, that means getting as far away from city lights as you can. The glow from bright artificial lighting can nearly wash out faint, fuzzy objects like comets. If you want to spot Shoemaker-Levy with your naked eye, you'll need a pitch-black site. But even if you plan on using a telescope to observe the comet, a dark sky will afford you a much better view.

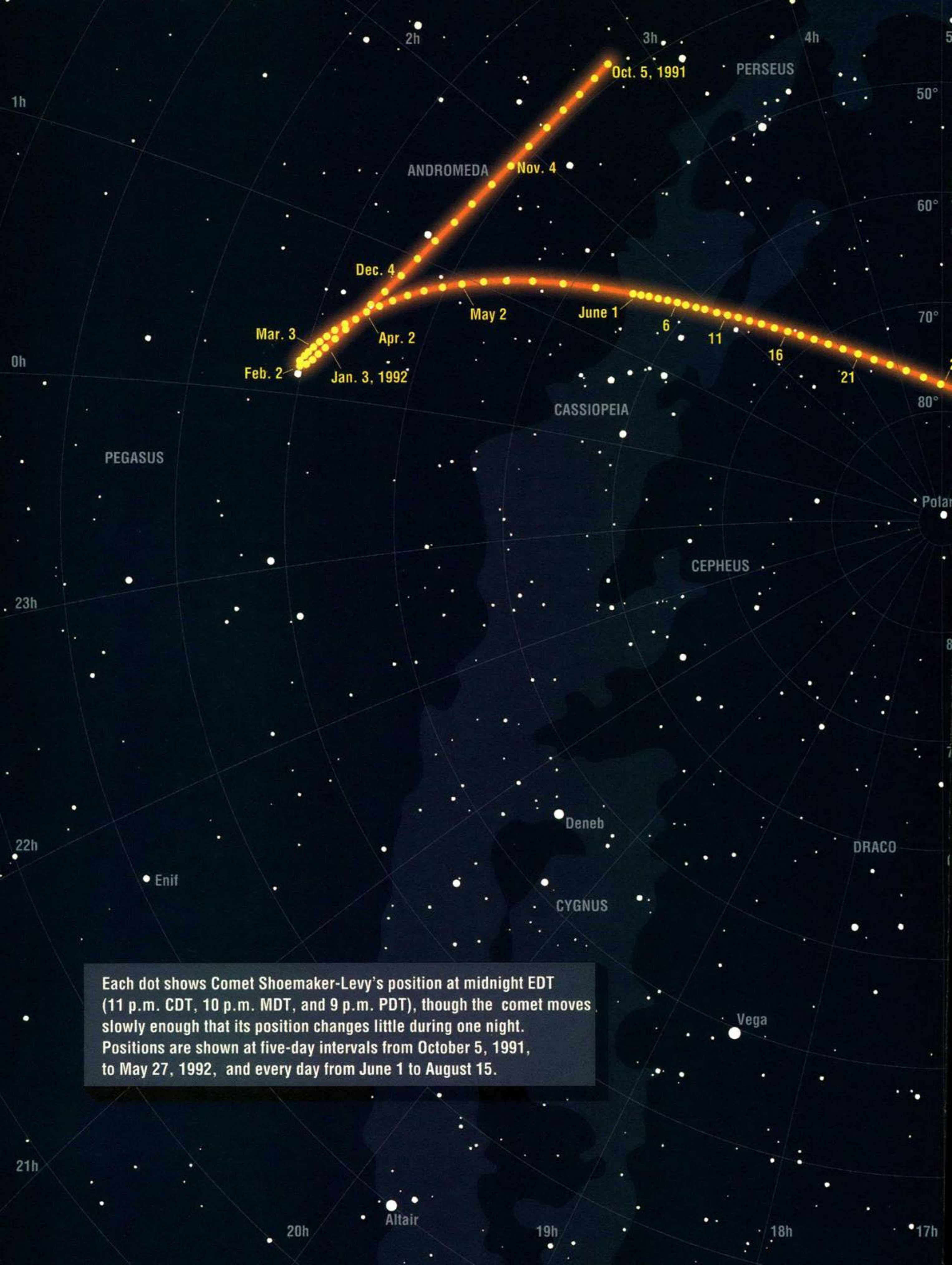
In the same way that artificial lights make comet hunting difficult, so does the natural light of a bright Moon. Avoid observing on nights when the Moon brightens the sky. The comet's northerly position in June and early July helps in this regard. If the Moon is bright in the evening sky, plan on observing the comet before dawn. Likewise, a bright Moon in the morning can be sidestepped by observing in the evening hours. Except on nights near the Full Moon, you can outmaneuver the Moon simply by picking the proper observing time. When the comet moves south in late July, it also moves into the evening sky. Fortunately the Moon is a morning object during this period, so you should still get a good view.

To get the best view of Shoemaker-Levy, however, bring along binoculars. A pair of 7x35 or larger binoculars will gather enough light to make the comet appear distinct against the starry background, even if the comet doesn't quite live up to expectations.

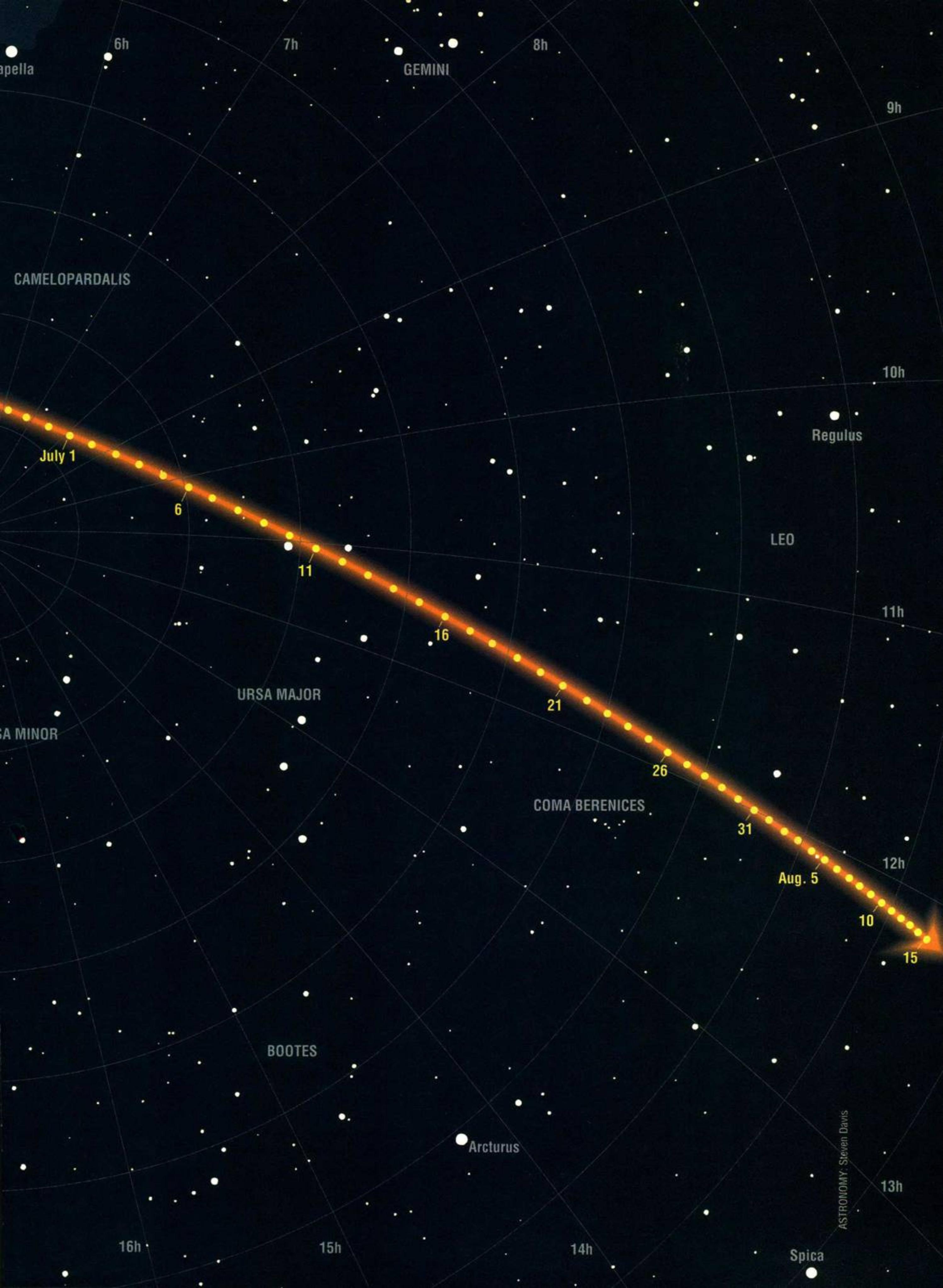
Binoculars are also the instrument of choice for viewing the comet's tail. Though Shoemaker-Levy probably won't produce a spectacular tail (it won't get close enough to the Sun for that), the tail could easily span a few degrees. Binoculars provide a wide

A COMET SHOEMAKER-LEVY CHRONOLOGY

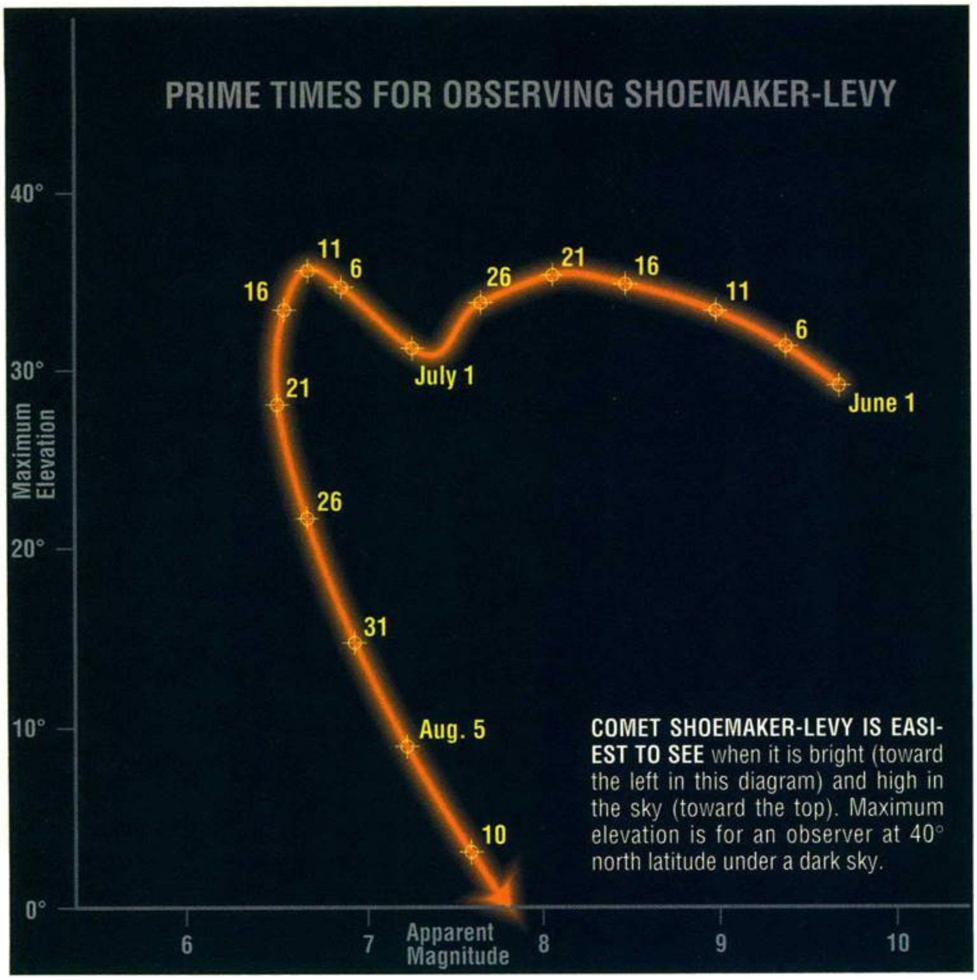
1991 — October 6 — Eugene Shoemaker, Carolyn Shoemaker, and David Levy discover the comet
1992 — June 29 — Reaches highest declination (79°)
July 6 — Passes 2° northeast of galaxies M81 and M82
July 12 — Passes 1° north of galaxy M108
July 13 — Passes 0.5° east of the Owl Nebula (M97)
July 14 — Approaches closest to Earth (83 million miles)
Mid- and late July — Shines at its brightest
July 24 — Approaches closest to the Sun (78 million miles)
Mid-August — Disappears from view for Northern Hemisphere observers


2h
3h
4h
1h
Oct. 5, 1991
PERSEUS
50°
ANDROMEDA
Nov. 4
60°
Dec. 4
May 2
June 1
70°
Mar. 3
Apr. 2
6
11
16
21
0h
Feb. 2
Jan. 3, 1992
80°
CASSIOPEIA
PEGASUS
Polar
CEPHEUS
23h
Deneb
22h
DRACO
Enif
CYGNUS
Vega
21h
Altair
20h
19h
18h
17h

Each dot shows Comet Shoemaker-Levy's position at midnight EDT (11 p.m. CDT, 10 p.m. MDT, and 9 p.m. PDT), though the comet moves slowly enough that its position changes little during one night. Positions are shown at five-day intervals from October 5, 1991, to May 27, 1992, and every day from June 1 to August 15.


6h
7h
8h
apella
GEMINI
9h
CAMELOPARDALIS
10h
Regulus
July 1
6
LEO
11
11h
16
URSA MAJOR
21
SA MINOR
26
COMA BERENICES
31
12h
Aug. 5
10
15
BOOTES
Arcturus
13h
16h
15h
14h
Spica

ASTRONOMY: Steven Davis



PRIME TIMES FOR OBSERVING SHOEMAKER-LEVY

COMET SHOEMAKER-LEVY IS EASIEST TO SEE when it is bright (toward the left in this diagram) and high in the sky (toward the top). Maximum elevation is for an observer at 40° north latitude under a dark sky.

enough field of view to show you the entire comet at once.

If you want to view details in the tail or get a closeup look at structure in the coma or gaseous jets near the nucleus, you'll need the additional light-gathering ability and magnification of a telescope. A good 6-inch or larger instrument at medium to high magnifications should offer a superb view.

A Guessing Game

Unfortunately, it's nearly impossible to predict how bright Comet Shoemaker-Levy will get. The magnitudes cited in this article are based on astronomers' best predictions of what will happen as the comet approaches the Sun. However, the comet could easily prove to be a couple of magnitudes brighter or fainter than the values given.

There's nowhere near as much uncertainty in the position of Shoemaker-Levy. Astronomers have enough observations to calculate a good orbit for the comet, so the positions shown on the map on pages 76 and 77 should be right on. The altitudes and azimuths given below are for an observer located at 40° north latitude. This approximates the view across the central United States and southern Europe.

The time to start observing Shoemaker-Levy comes after the Full Moon in mid-June. By June 20, the Moon has waned enough to allow you to spot the 8th-magnitude comet in the evening sky. Shoemaker-Levy then lies in Cassiopeia and appears 21° above the northern horizon as evening twilight ends. The comet becomes easier to see toward the end of June, when the Moon is New and the comet stands more than 30° high both when evening twilight ends and morning twilight begins. On the 24th, Shoemaker-Levy passes from Cassiopeia into the barren reaches of Camelopardalis, which will make spotting the comet easier.

Heading South

July offers the best opportunities for viewing Comet Shoemaker-Levy because it is brightest then and well placed in the evening sky. The first good observing window this month runs from the 1st to around the 11th. As in June, the comet is visible in both the evening and morning skies. Though the comet is higher at the end of evening twilight — about 35° above the northern horizon in the evening compared with 30° or less in the morning — the morning view is better once the Moon reaches First Quarter phase on the night of July 6/7.

This eleven-day period sees the comet hovering around 7th magnitude, bright enough to see easily in any pair of binoculars. Having reached its highest declination (79°) on June 29, Shoemaker-Levy in July begins heading south as well as east. On the 5th, it leaves Camelopardalis behind and moves into Ursa Major, where it is destined for some exciting conjunctions with deep-sky objects.

On the night of July 6/7, Shoemaker-Levy passes less than 2° northeast of the bright pair of galaxies M81 and M82. This is a perfect chance for astrophotographers who want to capture the comet along with these favorite deep-sky objects.

Although observing comets near the time of the Full Moon is not easy, some excellent conjunctions in mid-July make it worth the effort. On the night of July 12/13, Shoemaker-Levy passes just over 1° north of the bright galaxy M108. On the following night, the comet passes 0.5° east of M97, the Owl Nebula.

The next good observing window opens around July 20 and lasts until the end of the month. This is when Shoemaker-Levy is at its brightest, peaking at a predicted magnitude of 6.5. If conditions are perfect or if the comet brightens more than expected, this is the time to try to spot it with your naked eye.

Shoemaker-Levy continues its rapid motion southward now and moves out of the circumpolar sky and into the evening sky. Look for the comet between 15° and 30° above the western horizon as twilight comes to a close.

Though Shoemaker-Levy has no particularly exciting conjunctions during this period, with the comet at its brightest and our view of the tail at its best, this could be an exciting time for comet observers. The odds of a long tail are slim because Shoemaker-Levy doesn't get that close to the Sun, but if a tail does develop, this is the time to look for it.

Once August begins, viewing conditions deteriorate rapidly. Not only does the Moon return to the evening sky, but Shoemaker-Levy continues its plunge to the south. By August 13, the comet sets before evening twilight ends. As the Sun's glare swallows it from view, we'll all look back on the comet's brief visit. It certainly won't make us forget the great comets of the past, but if we're lucky and it meets or exceeds expectations, we'll all remember it fondly. ☐

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Going Digital with Color

Backyard astronomers are now creating digital images of celestial objects in color.

by Richard Berry

Since 1989, a new generation of low-cost electronic cameras has been revolutionizing backyard astrophotography. Aficionados of the new technology refer to the wonder cameras simply as "CCDs," which stands for "charge-coupled devices." The big attraction of CCDs is that they allow you to capture very faint deep-sky objects with much shorter exposure times than are possible with conventional film. Astrophotographers have also found CCD cameras great for obtaining high-resolution images of the Moon and planets.

CCD pictures are digital images — each picture is made of discrete picture elements called pixels. Each element records the level of light hitting it and sends that signal to a computer where the brightness value is stored as a number. The computer then reconstructs the image from the stored data and displays it on a monitor.

Until recently, all amateur CCD images were black-and-whites. Now color imaging has arrived for CCDs. ASTRONOMY readers saw Jack Newton's color CCD image of the Dumbbell Nebula on the February 1992 cover and, in the April issue, Don Parker's color images of Jupiter.

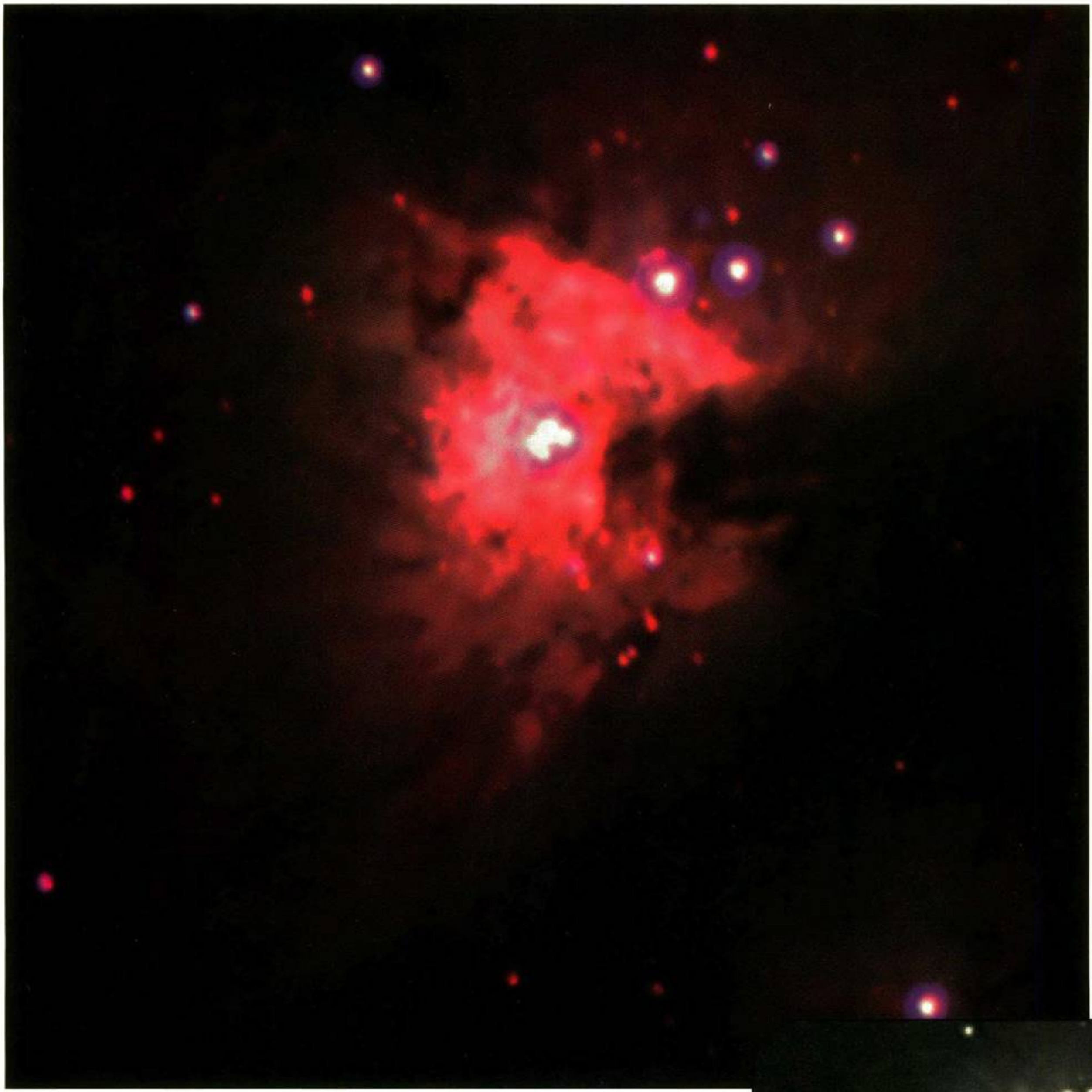
The move to color images is possible not because amateurs now have color CCD cameras — in fact, as the box on page 82 explains, for astronomy there's no such thing! — but because they are learning to convert black-and-white images into color ones using image-processing software.

Digital Color Shopping List

The basic requirements for color CCD imaging are the same as for black-and-white CCD shots. First, you need a CCD camera. Entry-level models capable of exposures of several minutes now go for $600 to $2,000. Most of these use a light-sensitive CCD chip with an array of 192 by 165 pixels. Cameras with larger arrays (1,000 by 1,000 pixels or more) provide a wider field of view. These premium models once cost $60,000 but are now coming down in price to within reach of hobbyist budgets.

Unlike conventional astrophotography, CCD imaging requires a computer. It needs to sit near your telescope where you can use it to control the camera as well as display and save images. (CCD cameras sometimes permit up to 100 feet of cable between computer and camera, but taking images then requires two people.) The computer requirements vary with the type of CCD camera, but an IBM or compatible equipped with 2 megabytes of RAM, a 40-megabyte hard disk, and VGA graphics (or an equivalent Macintosh) is the usual minimum.

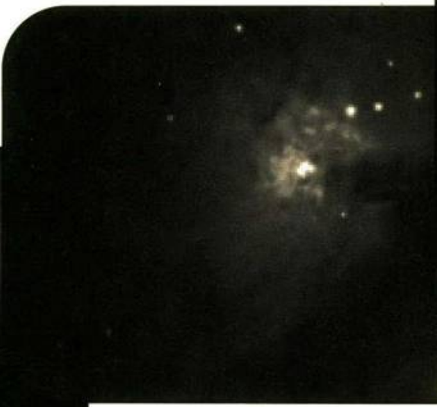
Of course, you also need a telescope. Because CCD chips are very small, the field of view of most CCD cameras is narrow. This means you don't need a large, long-focal-length telescope. In fact, telescopes considered small for conventional deep-sky



Jack Newton and Richard Berry, processing by Richard Berry

THE DIGITAL ORION NEBULA (above) was created by first using a CCD camera to take black-and-white images through red, green, and blue filters. These three images were combined in a computer to make a color composite.

BLUE-FILTERED IMAGE

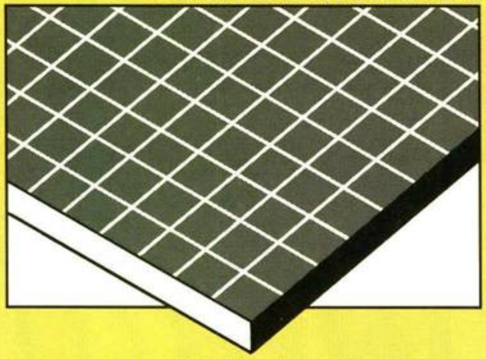


GREEN-FILTERED IMAGE

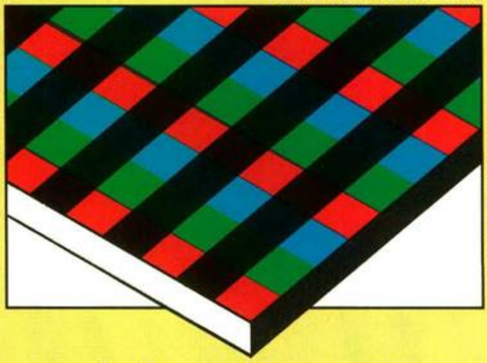
RED-FILTERED IMAGE

WHY NOT A COLOR CCD CHIP?

BLACK AND WHITE CCD CAMERA



COLOR CAMCORDERS



ASTRONOMY: Robert Wegner

Producing color images by taking three separate black-and-white exposures and combining them seems like a tedious process. Why not use a color camera? After all, home video cameras use charge-coupled device (CCD) chips and they produce color images. Why can't someone produce a color CCD camera for astronomical imaging?

The answer lies in how CCD cameras are built. The CCD chips in black-and-white cameras have a surface divided into thousands of rectangles (depicted in the left diagram). Each rectangle is a light-sensitive diode detector. When light strikes the diode, it generates an electrical signal that is stored on the chip. The signal from each diode is then read out by shifting the signal from diode to diode across the chip until the entire array's signal has been read into the computer.

In CCDs made for color camcorders (shown at right), an array of microscopic red, green, and blue filters is deposited right on the diodes during manufacture of the chip. This produces three separate color-filtered images in one exposure, which sounds ideal.

But there's a catch. Video CCDs need to work very quickly (30 exposures per second) so they use an arrangement in which alternate rows of diodes are covered with an opaque mask. When the chip is read out, the signals from the colored filtered diodes are shifted over one row to the diodes behind the opaque masks. Once there, the signals are protected from further exposure and can be read out as the next exposure is made.

This scheme prevents smearing in moving video images but it means that half the chip's surface is covered with an opaque layer. The half that is exposed to light is covered by red, green, or blue filters. If a pinpoint star image happens to fall on an opaque diode, it won't be recorded. If it falls on an exposed diode, it gets recorded only in the color of the filter that covers that diode. These limitations rule out the present generation of color CCD cameras for high-resolution astronomical imaging.

photography do very well for CCD imaging. Telescopes with 400 to 900mm focal lengths (such as 4- to 6-inch f/4 to f/6 scopes) provide more than enough magnification for framing individual galaxies and nebulae onto the tiny chip. With the 6-inch f/5 reflector I use, the Whirlpool Galaxy fills half the frame of my 192x165-pixel CCD camera.

For any long-exposure astrophotography, whether with film or a CCD, the scope should be equipped with a solid equatorial mounting and a smooth, reliable drive. Though CCD-camera exposures are often no longer than a few minutes, this is still long enough that you need to manually guide your telescope during the exposure. This requires either an off-axis guider or a separate guidescope.

Finally, to process the raw image captured by the computer requires image-processing software. Many cameras come with basic programs, and more sophisticated software packages are available from third-party suppliers. To create color images, however, you need a program that can electronically synthesize three black-and-white images into a single color frame. I know of only two commercially available programs at the moment that can do this: Aldus PhotoStyler, a program that runs on a PC under Windows and Adobe PhotoShop, which runs on a Mac. A third program, Astronomical Image Processing, Version 2, scheduled for release later in 1992, will include the ability to create color images directly from CCD black-and-white originals.

Splitting the Spectrum

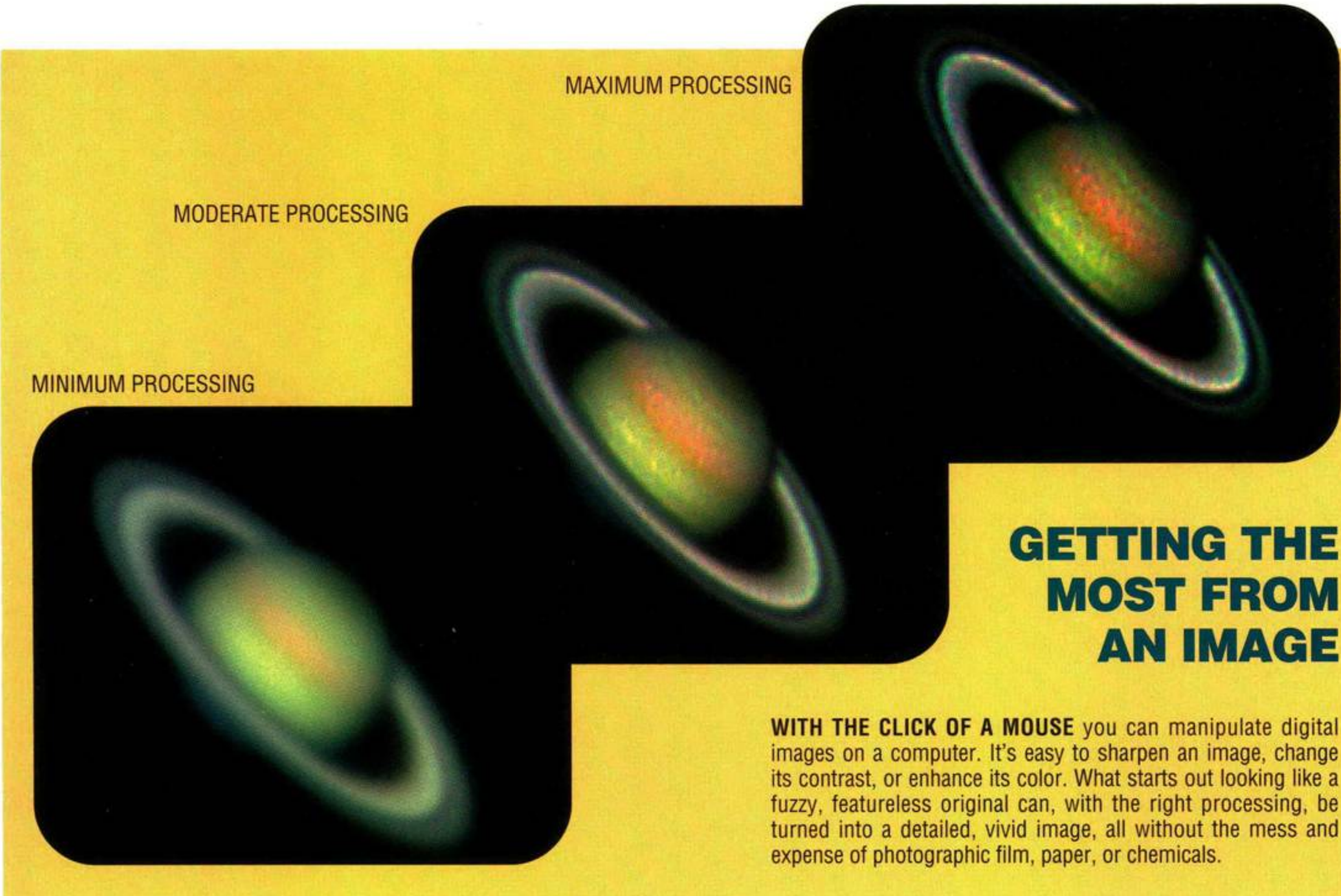
Before venturing into the field of color CCD imaging, it's best to be familiar with how any camera creates a color image. The underlying principle consists of recording the intensity of light at several different wavelengths, and then replaying those intensities into your eyes. Accurately recording how bright each object in a scene looks in the light of several colors allows you to later reconstruct the scene in full color.

This is exactly how color slides, color prints, color TV, and color CCD images work. Each of these media records the intensity of light in three colors — red, green, and blue. Mixing these primary colors allows you to create all the colors of the universe. Yellow and orange result when different amounts of red and green light combine. Magenta comes from mixing red and blue.

The most familiar example of a three-color recording process is color photography. Color film is actually made from three layers of black-and-white film, one sensitive to red light, one to green, and one to blue. (In practice, modern color films have a dozen or more layers, but the principle remains the same.)

When the film is developed, each light-sensitive layer takes on colored dyes in amounts that are proportional to the level of light that struck the film. When we place the finished film in a slide projector or view a color print, where the original scene was red, we see red, and so on.

Using multilayered color film is



Donald Parker, image processing by Richard Berry

GETTING THE MOST FROM AN IMAGE

WITH THE CLICK OF A MOUSE you can manipulate digital images on a computer. It's easy to sharpen an image, change its contrast, or enhance its color. What starts out looking like a fuzzy, featureless original can, with the right processing, be turned into a detailed, vivid image, all without the mess and expense of photographic film, paper, or chemicals.

the obvious way to make color astrophotos. In the 1970s, amateur astronomer Ronald Royer perfected another technique, one borrowed from the earliest days of photography. His method of "tricolor astrophotography" is to shoot three black-and-white negatives through color filters. He combines the negatives by making black-and-white enlargements and rephotographing the enlargements through red, green, and blue filters onto color film. Though time-consuming, the technique takes advantage of the greater sensitivity and finer grain of black-and-white film compared to color. As a result, the final composite exhibits more nebulosity with more vivid colors and greater sharpness than is possible with a single original taken on color film.

Old Technique, New Technology

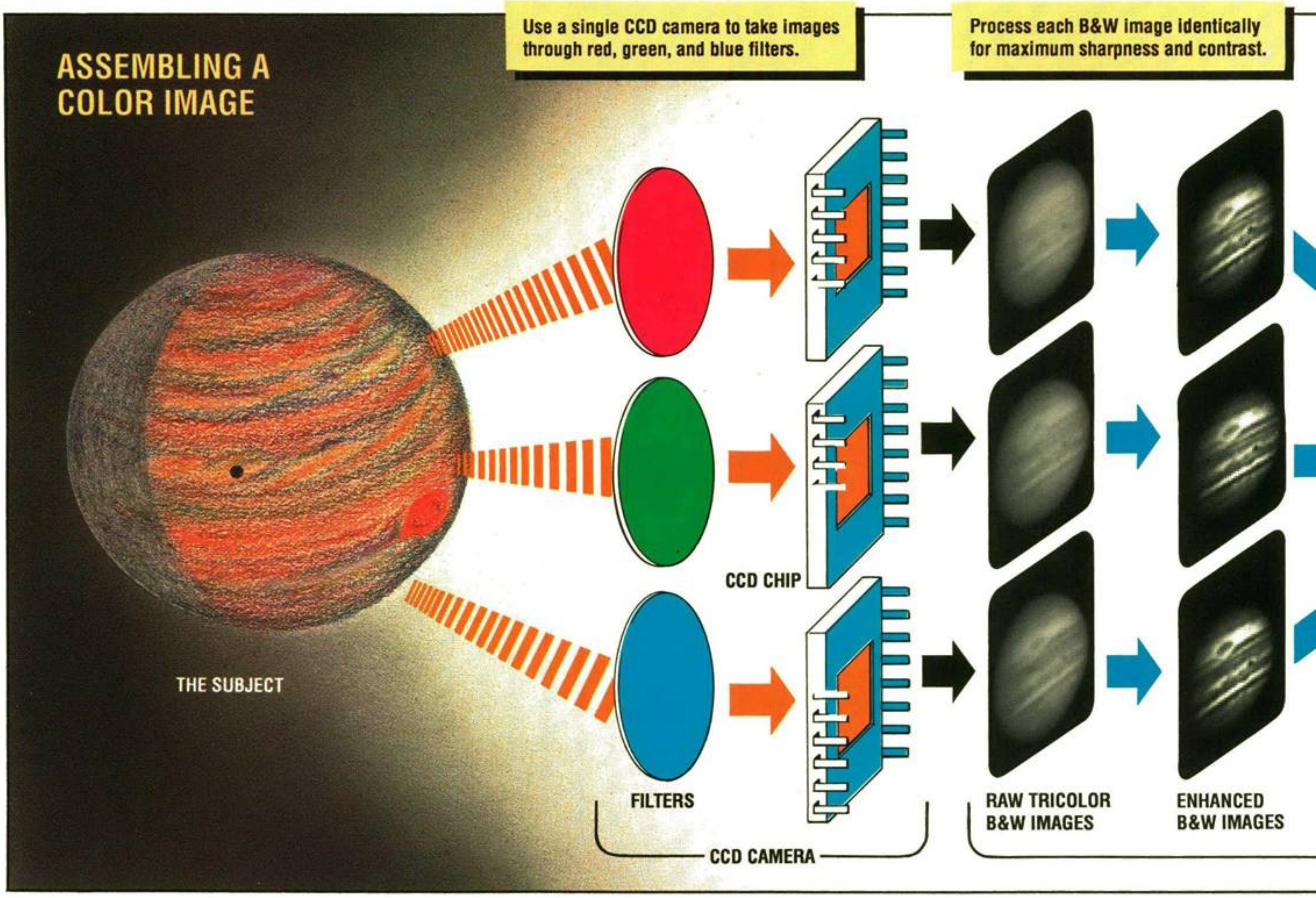
Before the invention of color film, manually combining three black-and-white photographs was the only method the pioneers of photography had to create true-color images. Today's pioneers of amateur CCD imaging are at that same stage. The way to create a color image with an astronomical CCD camera is to take three exposures — one through a red filter, one through a green, and one through a blue — and electronically superimpose them on a computer screen.

As recently as mid-1991, no amateur I know had done this. I decided, with the help of my friends Donald Parker and Jack Newton, to make color pictures with a CCD. Don and Jack are accomplished astrophotographers, and I enjoy writing computer software and reading arcane books about color theory. I've also done my share of astrophotography and CCD imaging.

In early 1991 Jack started taking digital images using one of the first-generation amateur-market CCD cameras. Although he bought it for guiding his 25-inch reflector, he got carried away taking images with it instead. Although we had talked about making color images, Jack threw down the gauntlet when he sent me a set of pictures of the Ring Nebula that he had taken through color filters and challenged me to make a color image from them.

Don started taking planet pictures with his CCD camera in mid-1991, using his 16-inch reflector and eyepiece projection. By the time I had figured out how to make color composites, Jupiter was lost in the evening glare. So Don's first tricolor images, seen in earlier issues of ASTRONOMY, were of Saturn.

Although shooting tricolor image sets may sound simple, it can be tricky to put into practice. For realistic results, you must use a filter set that separates the colors without much mixing. Wratten filters #25 red, #58 green, and #47 blue have long been considered the standard filter set for photographic tricolor work. For astronomical imaging, and nebular photography in particular, you need wider passbands to keep exposure times down. We recommend #23A light red, #56 light green, and #38A light blue for tricolor CCD imaging. You can buy these inexpensive filters at photo stores. For eyepiece projection shots of planets, all the major


ASSEMBLING A COLOR IMAGE
Use a single CCD camera to take images through red, green, and blue filters.
Process each B&W image identically for maximum sharpness and contrast.
CCD CHIP
THE SUBJECT
FILTERS
CCD CAMERA
RAW TRICOLOR B&W IMAGES
ENHANCED B&W IMAGES

COLOR CCD IMAGING is a multistep process — shooting three black-and-white images, enhancing them, and then combining them into a composite.

telescope companies sell filters that screw into eyepieces.

Had Don and Jack simply shot images through these filters, however, infrared light leaking through them would have rendered the images useless. (The silicon used to make a CCD chip is very sensitive to infrared.) So we added an extra filter to our filter sets, a Corion NR-400. This filter blocks very little visible light but cuts out the infrared entirely. A one-inch-diameter NR-400 filter costs $127.

To make changing filters easy, Jack made a set of filter holders that allow him to pop the tricolor filters into his camera adapter without rotating or moving the camera, a very important consideration. For Don's setup, he and his friend Bill Douglas constructed a motor-driven filter wheel that allows Don to change filters rapidly without touching the telescope. With Jupiter and Saturn, you have less than two minutes, and with Mars less than five minutes, to obtain a tricolor set before the planet rotates so much that the combined color image smears.

At the 1992 Winter Star Party in Florida, Jack took four sets of tricolor images. These images were possibly the first color CCD images taken at any star party. To do it, Jack borrowed Mark Wojcul's 7-inch f/9 refractor for four nights, as well as a portable computer to capture images from a prototype CCD camera Jack was testing.

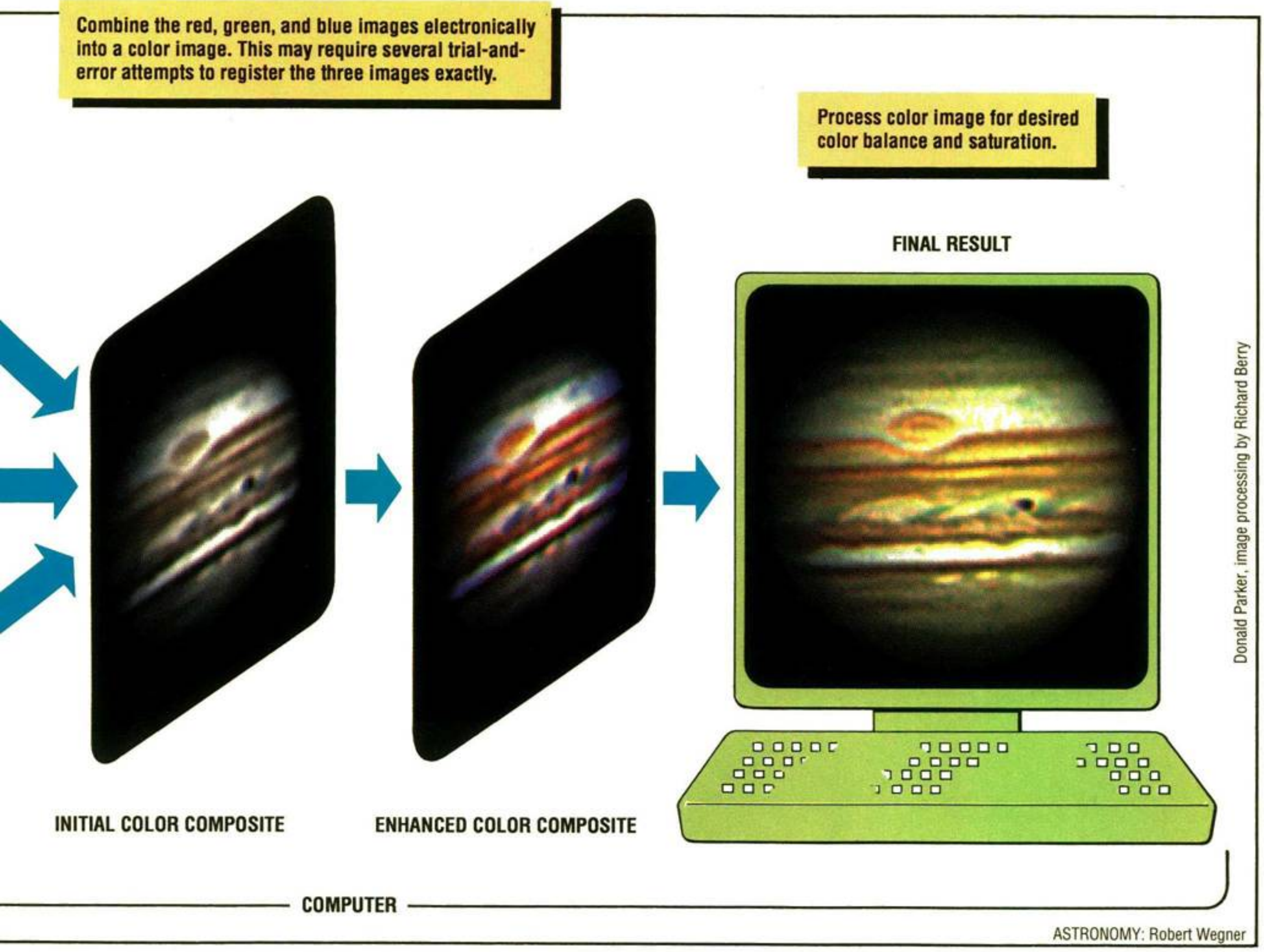
From experimental efforts such as these, Don, Jack, and I have learned some important lessons. Tricolor frames must be exposed well enough that the images are much stronger than the electronic noise. In Florida, the ten-minute exposures of deep-sky objects we shot through the blue and green filters were barely sufficient. Longer exposures or a faster telescope would have improved our black-and-white original images and made for better color composites.

The color filters needed for tricolor imaging exact a severe toll on light, as Don's best images of Jupiter and Saturn testify. The exposures, which are made with Don's 16-inch f/6 Newtonian using eyepiece projection at f/22, can run as long as 18 seconds for Saturn through the blue filter and 2 seconds through the red filter. However long these sound, corresponding exposures on film would have been ten times longer.

Getting It Together

If you were doing photographic tricolor work, after taking the three original black-and-white negatives, you would disappear into the darkroom for about six hours. But with CCD images the computer becomes your darkroom. Nevertheless, once you realize that software, a keyboard, and a mouse have replaced your trusty enlarger and trays of chemicals, making a digital color composite is much like making a color print in the darkroom. You go through the same steps.

With photography you first put your negative into the color enlarger. With digital imaging you start by loading the three black-and-white images


Combine the red, green, and blue images electronically into a color image. This may require several trial-and-error attempts to register the three images exactly.
Process color image for desired color balance and saturation.
FINAL RESULT
INITIAL COLOR COMPOSITE
ENHANCED COLOR COMPOSITE
COMPUTER

Donald Parker, image processing by Richard Berry

ASTRONOMY: Robert Wegner

into the computer. In photography I always began by making a test print just to get some feeling for the density and color balance of the negative. In computer processing, you can do a quick trial merge of the images. (With the right software, merging the color images is a matter of three clicks of the mouse.)

Now you evaluate the test strip. If the three images are not in perfect register, you nudge them around a bit. Hmm, it looks like the red image should go three pixels up and two pixels left. Then you merge the images again to see if they fit. After three or four tries you should have them reasonably close, and you can pay attention to the color balance.

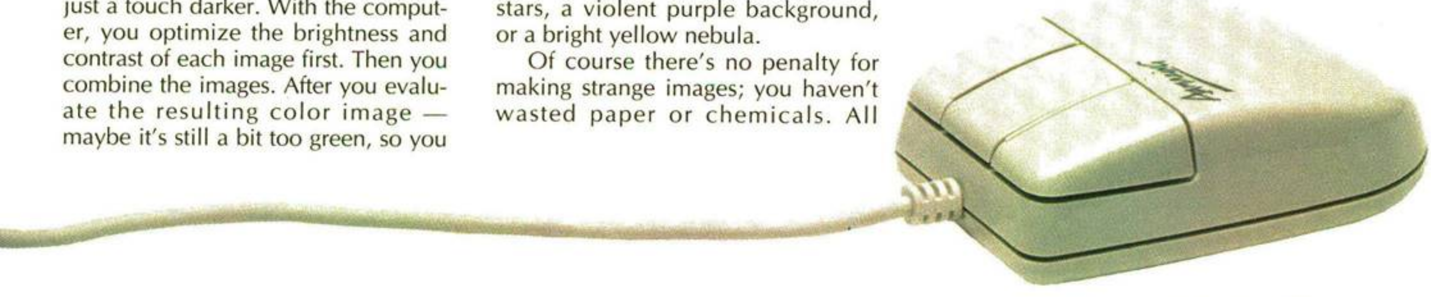
If you've made prints in the darkroom, you probably know how to change exposures and printing filters to make an image a bit redder and just a touch darker. With the computer, you optimize the brightness and contrast of each image first. Then you combine the images. After you evaluate the resulting color image — maybe it's still a bit too green, so you brighten the red image a tad — you try again. If you are adept with a computer and understand color printing from the darkroom, you should be able to assemble a color image from a raw tricolor CCD image set in under an hour.

Remarkably few pitfalls occur in creating color images on a computer. The most important thing to remember is this: process all three black-and-white images in the same way. Image-processing software gives you a palette of enhancement options: filtering, sharpening, contrast boost, unsharp masking — all designed to bring out the maximum detail in the original. Fine, go to it. But if you computer enhance one of the images without processing the other two with exactly the same steps, you'll get ghastly results — vivid color rings around all the bright stars, a violent purple background, or a bright yellow nebula.

Of course there's no penalty for making strange images; you haven't wasted paper or chemicals. All you've spent is your own time. And you can always try again.

So there you have it. Color CCD imaging provides amateurs with a satisfying sense of exploring a new realm. But in fact the newest technologies make use of tried-and-true methods. Although today's CCD cameras are ten times more sensitive to light than photographic film, the basic ideas behind color imaging with this state-of-the-art medium and the 150-year-old medium of photography remain the same. ☐

Richard Berry, former editor-in-chief of ASTRONOMY, writes books about astronomy and computer software. His forthcoming book is How To Use a CCD Camera *(Willmann-Bell, Inc., 1992).*



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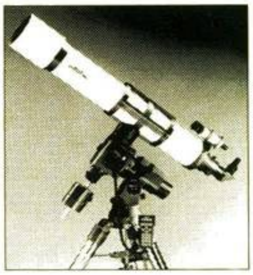
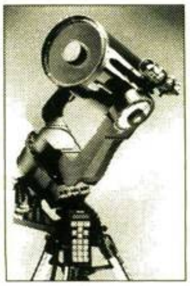


Shown: several of Meade's new APD telescopes



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6"	105.00	6"	95.00
8"	125.00	8"	109.00
10"	139.00	10"	119.00
11"	149.00	11"	139.00
12.5" to 13.1"	179.00	12.5" to 13.1"	159.00
14"	199.00	14"	179.00
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GOOD GEMINIDS!

Many readers bundled up, braved the winter cold, and viewed the Geminid meteor shower last December (see April Reader Reports). The numbers for the Geminid shower were high: George W. Gliba of Greenbelt, Maryland, reported 102 Geminids over a four-hour period on December 15, the night of peak activity.

Rob Donner of Goleta, California, counted 116 meteors on December 14, between 1:00 and 2:15 a.m. PST. The hourly rate derived by Donner is 92. "We observed the shower from a dark site along the cliffs of Isla Vista, California," reports Donner. "Most were the typical short, bright meteors with a strong yellow color. I saw one bolide break into five pieces and dramatically fall toward the Pacific Ocean."

Nova Cygni 1992. The brightest nova in several years attracted throngs of observers to the eyepiece in February and March 1992. George Gliba observed the nova every morning between February 21 and March 13, watching the ruddy star fade from magnitude 4.6 to 6.5. "For the last three days," writes Gliba, "the nova appeared to stop fading and held fast at about magnitude 6.5. Perhaps it will soon fall again, but for now I am enjoying watching it through my 8x50 binoculars."

Those Eclipsed Rays. Richard Zito and Mark A. Mattox of Sunnyvale, California, report that "although the article on observing lunar rays in the April issue suggests Full Moon is the best time to see rays, the *absolute* best time is during a lunar eclipse." During those rare events lunar rays stand out as particularly high contrast wisps, Zito and Mattox contend. "Perhaps the superb contrast of the rays against the Moon's disk is due to the fact that the eye is not overwhelmed by the brightness of the Moon's disk," they say. Of course lunar eclipses don't occur every month, but this advice is something to tuck away, or better yet place on your checklist of activities for this December's eclipse of the Moon.

Noctilucent Cloud Observer's Network. Thousands of observers were happy to see last November's impressive display of aurorae. However, a smaller group stalks a different atmospheric phenomenon with camera and notebook. "Noctilucent clouds — consisting of dust or ice — form over the mesosphere, 85 to 100 kilometers above Earth's surface," explains Mark S. Zalcik of Edmonton, Alberta, coordinator of the 34-member NLC CAN AM (Canadian-American noctilucent cloud observers) group. "The 1991 season for noctilucent clouds was comparable to that of 1990, but weaker than the seasons of 1988 and 1989," reports Zalcik. Noctilucent clouds were visible on 34 nights last year, mostly in mid-summer, while observing late in the year was hampered by dust from Mt. Pinatubo. A display on June 18/19, 1991, was witnessed by Chris Spratt of Victoria, British Columbia, who became the network's southernmost observer of this normally high latitude phenomenon. For more information, contact Mark S. Zalcik, 9022 132 A Avenue, Edmonton, Alberta T5E 1B3, Canada. — *David J. Eicher.*

A BRILLIANT GEMINID FLASHES through the heart of the Orion Nebula (right) in a photo taken by Mirco Villa on December 15, 1991. Nova Cygni 1992 was a target for many astrophotographers, including W.D. Baldwin of Jacksonville, Florida. Baldwin's photo (below) shows the nova marked with an arrow.

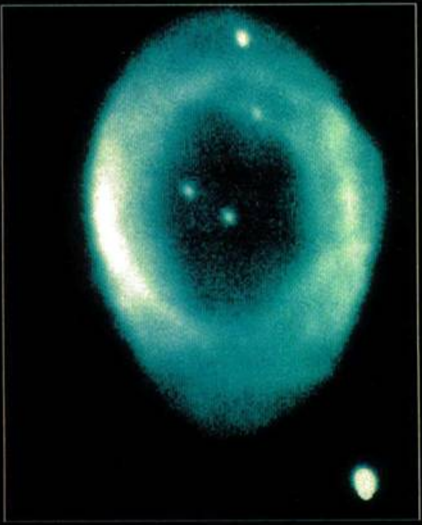
GOLDEN ECLIPSE MEMORIES

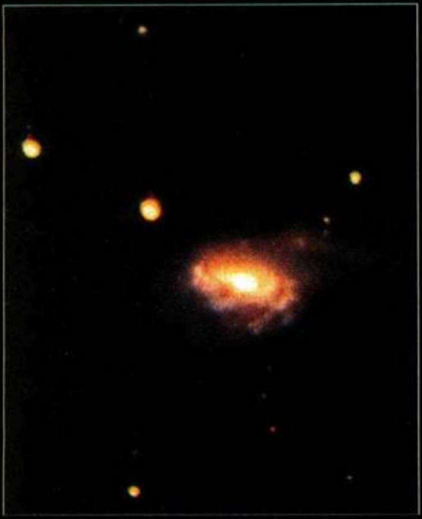
This year's solar eclipse in South America is reminding amateurs of last year's spectacular event. Among the many new submissions of 1991 eclipse photos we've received is David Nelson's fisheye lens shot of the eclipse (opposite page), which wins this month's $100 "Best Astrophoto" award. Nelson photographed the eclipse from La Paz, Baja California. Jupiter and Venus are visible below the eclipsed Sun.

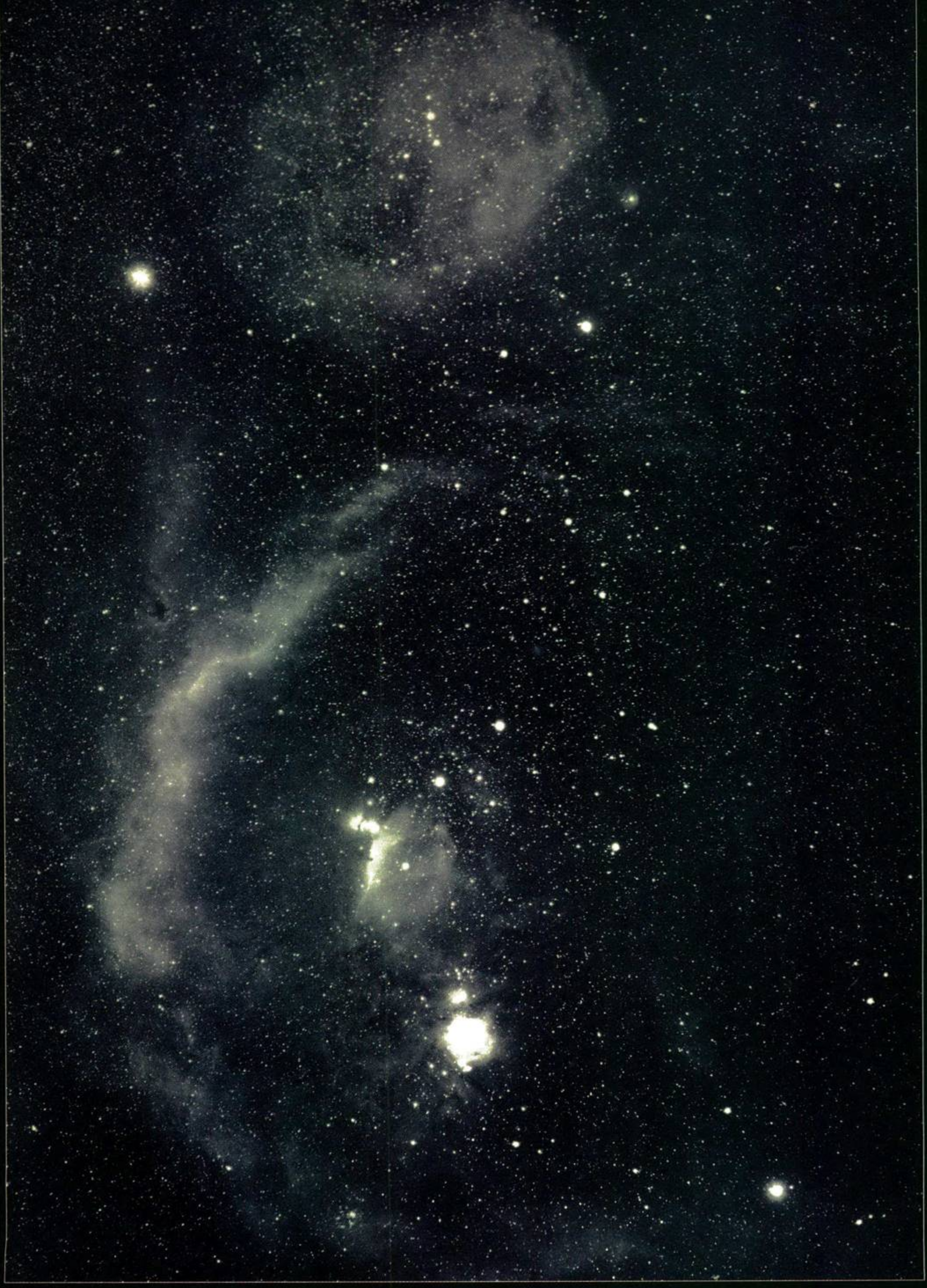
Last year was also a banner one for aurorae. In June 1991 Greg Forbes captured this spectacular auroral curtain and scattered backlit clouds (left) from an observing site near Columbus, Indiana.

Comet Mueller (1991h[1]) was discovered on December 18, 1991, and was visible during early 1992. Gerald Rhemann of Vienna, Austria, photographed the comet's bright coma and wisp of tail using a Schmidt camera (bottom).

Deep-sky objects are perennial favorites for readers with an astrophotographic bent. Canadian astrophotographer Jack Newton captured a tricolor CCD image of the bright galaxy M66 using his 11-inch f/10 SCT (bottom left). The CCD camera at the NCU Observatory in Chungli, Taiwan, permitted Hungchun Lin to record a closeup image of the Ring Nebula in Lyra (below left). Steve Quirk of Mudgee, New South Wales, Australia, recorded the subtle spiral arms of galaxy M83 using more conventional methods — a 12.5-inch reflector and Ektar 1000 film (below).







ENVELOPED BY NEBULOSITY, the constellation Orion is difficult to recognize in this extraordinary image. Robert Townsend used an 85mm lens and nearly four hours of exposure time to capture the delicate beauty of this rich region of sky.

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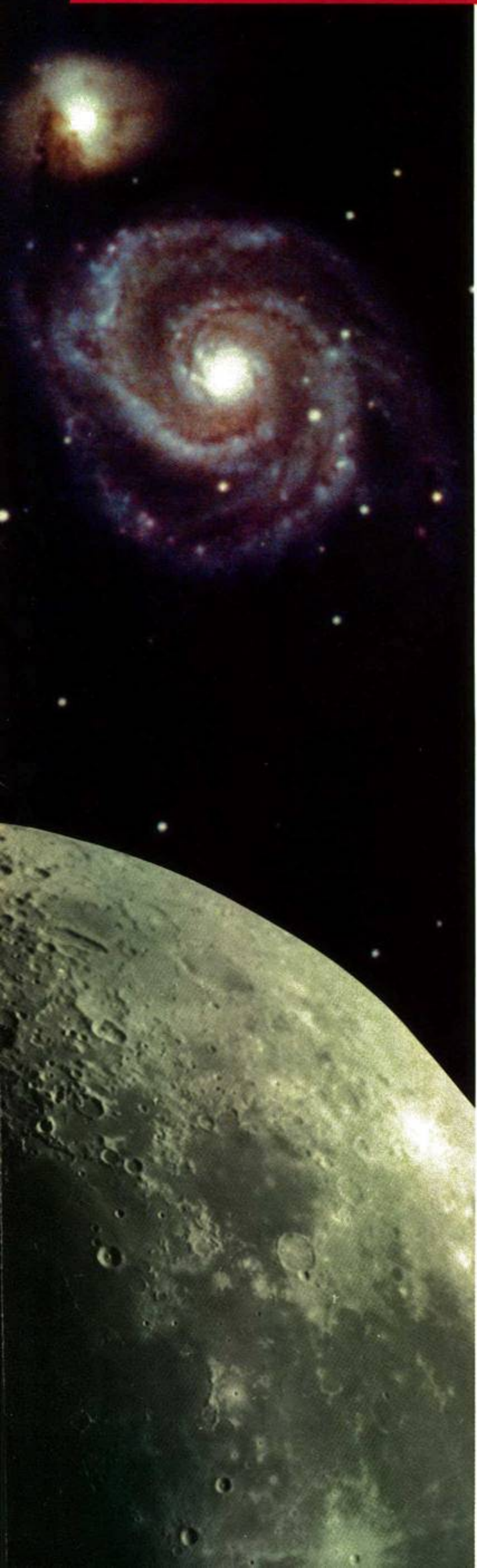

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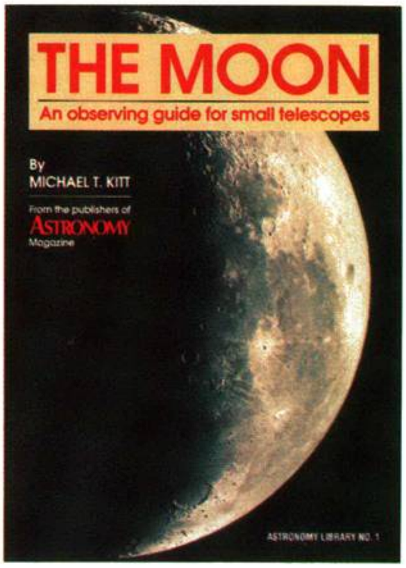
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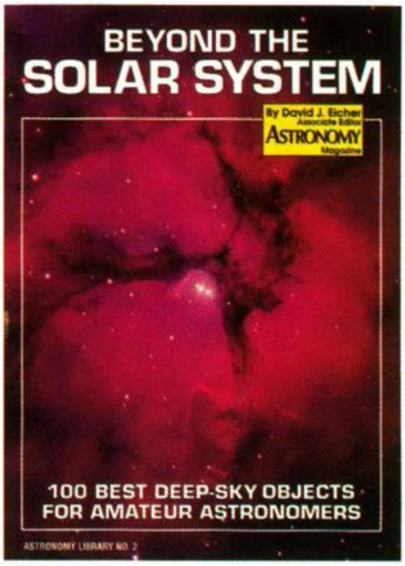
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This book concerning the folklore and mythology about the Moon is absolutely enchanting. It's a perfect volume for those nights of observing that turned cloudy or for those times when you're trying to shake out the cobwebs after reading some dull, technical prose.

Cain uses modern ideas concerning the Moon's formation, radioactive dating of lunar rocks, and the Apollo Moon missions as jumping off points to retell the legends and stories of different cultures. She regales the reader with tales about the figures different cultures have seen in the Moon's markings and with folklore concerning weather prediction using the Moon. And she tells us about the Moon's place in the calendars of the Greeks, native Americans, Mayas, Celts, Chinese, Hawaiians, and others. Cain also asks why the lunar missions were named after the Sun god.

The book is a gold mine of lunar lore. (For example, every note in Chinese music has a special relationship to the universe. E-flat is the Moon's sound.) Pre-Columbian inhabitants of Peru used the same word for Moon, sea, and woman. The Chinese had 28 Moon stations, and Hawaiians had names for the 28 lunar phases. Lunar festivals, music, poetry, a recipe for mooncakes, and the names of the Moon used by different peoples from Hittite to Hottentot round out the book.

Every time you open this book, you find a new treasure, yielding hours of pleasure-filled exploration. Cain captures the essence of human feelings about the Moon that transcend culture and time, revealing the human struggle to understand the nature and origin of mysterious Luna (named for the Roman Goddess of the Moon). This book belongs on your shelf next to Allen's *Star Names. — Dave Bruning*

Moons of the Solar System, by John Stewart, (McFarland and Company, 1991), 244 pages, ISBN 0-88950-568-6, sewn binding, hardcover, $45.

Stewart's reference book provides encyclopedic listings for lunar maria and craters and the satellites of other planets. The lunar crater and mare entries describe each feature's position and diameter. The crater entries also list nearby craters for reference and the person the crater was named after. Many entries describe the crater's physical appearance.

Entries for the other satellites include orbital information, pronunciation guides, physical characteristics, the circumstances regarding the object's discovery, the mythological character for which the satellite is named, and other names (for example, Adrastea is also known as Jupiter XIV, J14, and 1979 J1). The positions and descriptions of named surface features accompany each satellite's entry.

At the end of the book, Stewart provides several useful appendices organizing the satellites by size, planet, apparent brightness, and discovery date. An additional appendix lists the space probes — and their launch dates and encounter dates — that have studied or discovered planetary satellites.

Stars

Sky Catalogue 2000.0, Volume 1: Stars to Magnitude 8.0, second edition, by Alan Hirshfeld, Roger W. Sinnott, and François Ochsenbein, (Cambridge University Press and Sky Publishing Corp., 1991), 682 pages, ISBN 0-521-41743-0, sewn binding, hardcover, $64.95; ISBN 0-521-42736-3, sewn binding, softcover, $39.95.

Improved magnitudes and a more complete search at the catalog's limiting magnitude have expanded this reference work of stellar positions, magnitudes, colors, spectral types, and distances by almost 11 percent, to 50,071 stars. New features include constellation names for every star, Yale Bright Star Catalogue numbers (in addition to the HD and SAO numbers), a cross reference to selected variable stars, and further notes for selected stars, which include star cluster memberships.

Space

A Spacefaring Nation, edited by Martin J. Collins and Sylvia D. Fries, (Smithsonian Institution Press, 1991), ISBN 0-87474-907-7, 245 pages, acid-free paper, sewn binding, hardcover, $35.

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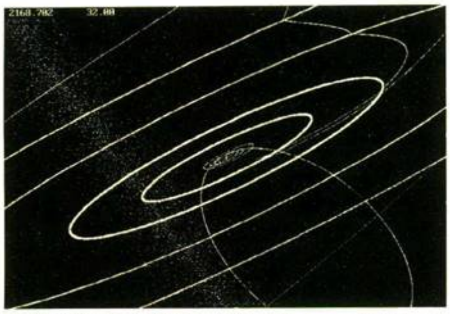

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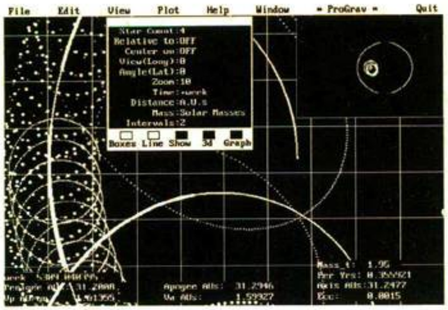

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Relative to:OFF
Center on:OFF
View(Long):0
Angle(Lat):0
Zoom:10
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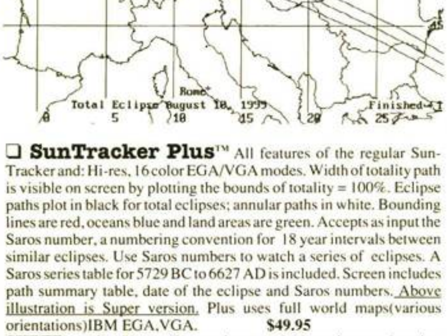

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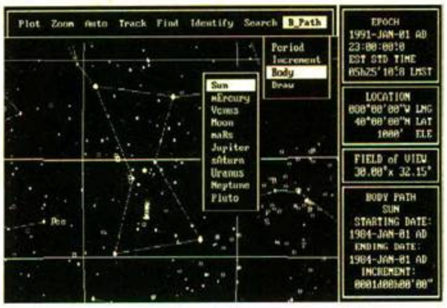

```
EPOCH
1991-JAN-01 AD
23:00:00.0
EST STD TIME
05h25'10.8 LMST

LOCATION
000°00'00"W LNG
40°00'00"N LAT
1000'   ELE

FIELD of VIEW
30.00°x 32.15°

BODY PATH
SUN
STARTING DATE:
1984-JAN-01 AD
ENDING DATE:
1984-JAN-01 AD
INCREMENT:
0001d00h00'00"
```

```
Partial Solar Eclipse
Magnitude: 0.170  Obscuration:   0.3x
LAST CONTACT
```

```
(***    NGC 3034  Located at TARGET    ***)
NGC# ObjTyp Cst  Mag Type          Size
3034 Galaxy UMA  9.5               11'x 5'
(CIRCUMPOLAR)   TT: 17h35'20.3   (CIRCUMPOLAR)
```

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the idea for the Hubble Space Telescope, the relationship between space technology and planetary science in the years 1950 to 1988, and the decision to build the space station.

Spacecraft Tables 1957-1990, by Jos Heyman, (Univelt, Inc., 1991), 231 pages, ISBN 0-912183-07-1, softcover, $60.

Extensive tables grouped by mission class enable the reader to find the launch date, re-entry date, and international designation of any of the more than 4,100 spacecraft launched during the first 33 years of space travel. Heyman makes the sometimes frustrating experience of trying to find information about a given spacecraft easier by including indices that order the spacecraft by name and launch date.

Astrophysics

Astrophysical Formulae, second corrected and enlarged edition, by Kenneth R. Lang, (Springer-Verlag, 1980), 783 pages, ISBN 0-387-55040-2, sewn binding, softcover, $49.

This standard reference book of fundamental astrophysical formulae is now available in paperback. Lang includes over 2,100 formulas most useful to astronomers and over 1,900 bibliographic references from which he compiled the formulae. Although they do not form the major emphasis of the book, 69 tables describe the positions and physical data of the Sun, planets, planetary nebulae, white dwarfs, star clusters, galaxies, and quasars.

General Books

1991 Update to the Quick Reference Guide to ASTRONOMY Magazine 1973-1990, by Jack Hobart, (Geoimages Publishing, Inc., 1991), 2 pages, 25¢. [Publisher's address: Geoimages, P.O. Box 45677, Los Angeles, CA 90045; include a self-addressed, stamped envelope.]

This addendum to the *Quick Reference Guide* lists, by subject matter, feature articles and selected photos appearing in the 1991 issues of ASTRONOMY.

Isaac Asimov's Guide to Earth and Space, by Isaac Asimov, (Random House, 1991), ISBN 0-679-40437-6, sewn binding, hardcover, $19.50.

A set of 111 questions provides a springboard for short essays about Earth, the Moon, planets, stars, galaxies, and the universe. Asimov interweaves a brief historical background and scientific explanation for the general reader in many of the essays. □

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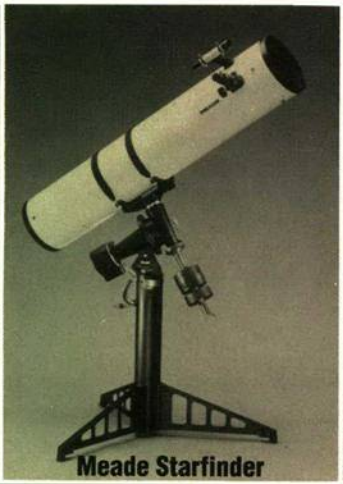

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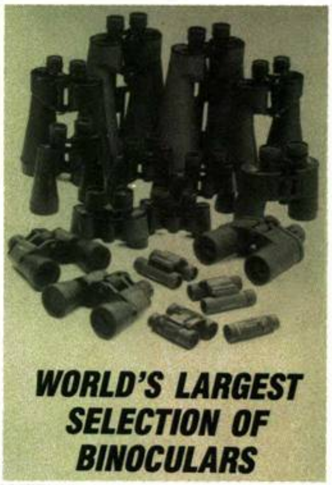

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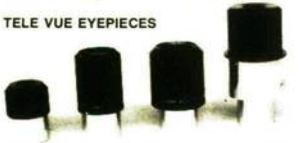

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19mm Wide-Field, 1¼" eyepiece, 65°	$145
24mm Wide-Field, "superb," 65°	$169
32mm Wide-Field, 2" eyepiece, 65°	$239
40mm Wide-Field, "awesome," 65°	$299
4.8mm Nagler, 82° field	$149
7mm Nagler, 1¼" eyepiece, 82° field	$189
9mm Nagler, 82° field, "the best"	$219
11mm Nagler, 82° field, 1¼" or 2"	$235
13mm Nagler, 82° field, 1¼" or 2"	$249
12mm Nagler, Type II, 82°, 1¼"/2"	$249
16mm Nagler, Type II, 82°, 1¼"/2"	$289
20mm Nagler, Type II, 82°, 2" only	$340
1¼" Paracorr Visual Coma Corrector	$179
2" Paracorr Visual Coma Corrector	$298
NEW! 22mm Panoptic 1¼"/2", 68°	$249
NEW! 35mm Panoptic 2", 68° field	$325

ADJUSTABLE PIGGYBACK MOUNT

The LUMICON adjustable piggyback mount is ideal for telescopes of 6-16" aperture. It permits **both** vertical and sideways adjustment for optical alignment. Also ideal to mount LUMICON 80mm SUPER-FINDER™, large telephoto lenses and small telescopes up to about 5 lbs.

LUMICON Adjust. Piggyback Mount **$59.50**
Specify telescope size: 6", 8", 10", 11", 14", 16"

H-ALPHA PASS FILTER

Yields spectacular contrast gains in B&W photograph with telephoto lenses. Yields pinpoint star images. Superb with hypered 2415. For color, use the Minus Violet (MV) Filter.

Specify Lens Size	**H-Alpha**	**(MV)**
46, 48, 49mm	$49.00	$39.00
52, 55, 58, 62mm	$59.00	$49.00
67, 72, 77mm	$69.00	$59.00
82mm	$79.00	N/A

Hypered 2415 film, 36 exp .. **$10.95, $3/$29**

LUMICON®
2111 Research Dr. #5A, Livermore, CA 94550
For phone orders please call (510) 447-9570
FAX (6 PM-9 AM PST) (510) 447-9589
LUMICON Products catalogue FREE
All foreign orders add 8% ($10 minimum)
California residents add 8.25% tax.
Prices subject to change w/o notice.
Hrs: M-F 9 am - 5 pm, Sat. 11 am - 3 pm

C-14 SALE!
ONLY $6450 (Was $7995)

Celestron C-14, f/11 Schmidt-Cassegrain telescope system. The Celestron C-14 is the ultimate in compact large aperture telescopes. It is ideal for all serious viewing and astrophtography.

SALE ENDS JUNE 30, 1992

Celestron C-14, complete 14" f/11 telescope system with starbright coatings, 8X50mm finder, 4 eyepieces, sturdy fork mount and precision worm gear drive system ($13,998 list)	$6450*
C-14 wedge and tripod ($1616 list)	$998
Deluxe dual-axis drive corrector	$398
LUMICON Giant EASY-GUIDER for f/6-f/11 viewing and astrophotography	$395
48mm LUMICON DEEP-SKY Filter	$119.50
Set 48mm UHC & DEEP-SKY filters	279.50

**Shipped f.o.b. Torrance, California*

LUMICON FILTERS — BEST IN THE WORLD!

"The LUMICON OIII proved to be our favorite... It gave the greatest contrast gain."
ASTRONOMY February 1991

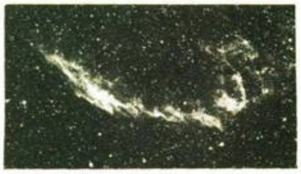
AMAZING OIII FILTER™

Helix Nebula, NGC 7293 in Aquarius. Bright and easy with Lumicon Oxygen-III Filter.

The ultimate in filter performance! The Lumicon Oxygen-III Filter has a contrast twice as high as the high performance Lumicon UHC Filter™. Use the Oxygen-III Filter for observing the very faintest planetary and diffuse emission nebulae. Also gives incredible views of bright nebulae (like M-27, M-17, etc.) from urban locations. Bandpass is 11nm, transmission is 90-96% for both O-III lines at 496nm and 501nm.

SEE THE HORSEHEAD!

Horsehead Nebula in Orion. This faint nebula is seen best with a LUMICON H-Beta Filter. Photo by J. Marling using a Deep-Sky Filter.



"I CAN SEE THE VEIL NEBULA!"

Rich Zepernick saw the Veil Nebula for the very first time with a **LUMICON UHC Filter**. He stated, *"It was actually there! and not just around 52 Cygni, but the whole loop! Words cannot possibly express my feelings. I don't know how I managed without these filters."*
Rich Zepernick, Cresskill, NJ

DEEP-SKY FILTER™

BEST for Astrophotography!

"Stunning is all I can say," says noted astrophotographer Jack Newton. Great for BOTH color and black and white photography.

BEST WIDE-BAND FILTER!

*"Based on our tests we'd recommend a LUMICON Deep-Sky and Oxygen-III as complimentary filters. The LUMICON Deep-Sky Filter clearly had the best contrast for **reflection** nebulae."*
Astronomy, Feb. 1991

	Premium*
0.96" LUMICON DEEP-SKY Filter threads into most 0.96" eyepieces	$59.50
1¼" LUMICON DEEP-SKY Filter threads into most 1¼" eyepieces	$79.50
48mm LUMICON DEEP-SKY Filter (1.7" aperture), threads into most 2" eyepieces. Also fits LUMICON EASY-GUIDERS	$119.50
2" LUMICON DEEP-SKY Filter (1.5" aperture), threads into most 2" eyepieces. Also has male & female camera T-threads for prime focus photography	$119.50
72mm LUMICON Giant DEEP-SKY Filter (62, 67, 77mm adapter, $8)	$299.50
1¼" LUMICON UHC Filter threads into most 1¼" eyepieces	$99.50
48mm LUMICON UHC Filter (1.75" aperture) fits most 2" eyepieces	$199.50
Set of both premium **DEEP-SKY** and **UHC Filters** (Save 11%) ... 1¼" **$159.50**; 48mm	**$279.50**
LUMICON H-BETA Line Filter (9mm bandpass at 486nm). For the California Nebula, Horsehead Nebula, and other extremely faint nebulae. **1¼"** **$99.50, 48mm**	$199.50
Oxygen-III Filter for very faint planetary and diffuse nebulae, 11nm bandpass at 496nm and 501nm O-III lines **1¼" $99.50, 48mm**	$199.50
Telephoto lens adapter for 2" or 48mm filter. Select 46, 49, 52, 55, 58mm	$6.95
Universal adapter for 1¼" filters. Adapts the 1¼" filters to any 1¼" eyepiece	$16.00
Universal adapter for 48mm or 2" filters. Allows use of any 1¼" eyepiece	$20.00

**Premium filters are currently the best in the world. All Lumicon filters include individually measured transmission data.*

DEEP-SKY ASTROPHOTOGRAPHY

SR-V 3200 NEW FILM

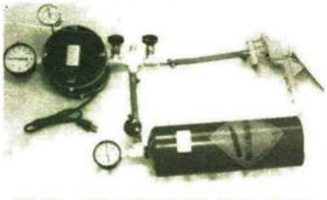
FILM HYPERSENSITIZATION KITS†

LUMICON HYPER-KITS™ yield 3-15x film speed gain in long exposures. They are safe & simple to use. Easy HYPER-KIT includes a chamber with all controls and fittings, thermometer, a refillable cylinder of non-flammable forming gas & hand-operated vacuum pump.

U.S. Patent 4,473,636

MAKE YOUR OWN HYPERED FILM

MODEL 300 HYPER-KIT sensitizes any 35mm film in hours. Best for 2415. Achieves highest possible film speeds **$325**



MODEL 600 HYPER-KIT (See photo) Like the Model 300, but also sensitizes 120/220 larger format film and small glass plates **$395**

MODEL 1200 HYPER-KIT is for 4X5" plates and film up to 5X7". Has 2 gas cylinders and includes temperature controller ... **$595**

Temperature controller for any HYPER-KIT **$65**

Electric Vacuum Pump, Model R-10 **$325**

GUIDE OFF-AXIS FOR LOVELY ASTROPHOTOS

All **LUMICON EASY-GUIDER™** off-axis guiders† have both radial and 360° rotational adjustments for 5X easier guide-star selection, use 48mm filters, 360° camera rotation, large prisms for bright guide-stars.
Specify Camera and Telescope type.
U.S. Patent 4,448,500

NEWTONIAN EASY-GUIDER™

Full aperture. Installs in seconds. Specify 2" or 1¼".

NEWTONIAN EASY-GUIDER	**$169.50**
3X Relay Diagonal (see photo)	**$89.50**
Illuminated reticle eyepiece system	**$99.50**
Guider for Hasselblad **$350,** Mamiya 645	**$199**
Pentax 6X7 **add $119;** Pentax 645	**add $139**

CASSEGRAIN EASY-GUIDER™

For C-8, Meade 2080, Cynamax-8. Includes 50mm achromatic lens for f/5.8 operation—3X shorter exposures! **Superb rich field viewing, too!**

CASSEGRAIN EASY-GUIDER	**$225.00**
Adapter for Hasselblad **$198,** Mamiya 645	**$98**
Pentax 6X7 **add $119;** Pentax 645	**add $139**

GIANT EASY-GUIDER™

For Celestron-11, C-14, and the 10" Meade 2120. Includes 80mm clear aperture achromatic lens for edge-to-edge illumination & pin-point star images. F-ratio adjustable f/4-f/11. **Also yields unmatched Rich-Field viewing.**

GIANT EASY-GUIDER	**$395.00**
48mm DEEP-SKY Filter ordered with any EASY-GUIDER (SAVE $20)	**add $99.95**
Adapter for Hasselblad **$229,** Mamiya 645	**$129**
Pentax 6X7 **add $129;** Pentax 645	**add $149**

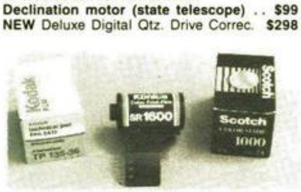
WHAT DO YOU NEED?

1. Illuminated reticle eyepiece **$99.50**
Lumicon 12mm eyepiece system has adjustable LED illumination, dual crosslines, battery pack.

2. Cable release for long exposures .. **$9.95**

3. **LUMICON Quartz Drive Corrector** . **$219**
Dual-axis drive corrector is essential for astrophotography and/or field use of your telescope. 40Hz/80Hz variable output controls telescope drive. 60Hz Quartz reference ±12VDC Declination control output. Both 110VAC and 12VDC input for home or field use. Declination reverse switch for Newtonians.

Declination motor (state telescope) .. **$99**
NEW Deluxe Digital Qtz. Drive Correc. **$298**



HYPERSENSITIZED FILM

LUMICON Hypersensitized film is essential for good deep-sky astrophotography. Deduct 10% for 3 or more rolls (mixed o.k.). ***No C.O.D.s.***

Film Type, 35mm	**Exposures**	**Price**
2415, Ultra-fine B&W, red sens.	36	**$10.95**
SR-G3200, fastest of all, color neg	24	**$13.95**
Kodak Ektar 1000 fast, fine grain	*24*	**$12.95**
Fuji HG400 fine grain color neg.	12	**$10.95**
3M 1000, fastest slide film	12	**$12.95**
Fujichrome RD100, fine grain slide	24	**$12.95**
D-19 B&W Developer	1 gal.	**$6.95**

NEW MEADE® ADVANCED PRODUCTS AT LUMICON

"What an astouding combination of high performance and low price!" Jack Marling, Ph.D., owner of LUMICON

TOLL-FREE ORDER LINE 1-800-767-9576 EXPERT INFORMATION 1-510-447-9570 FAX 1-510-447-9589

NEW ED APOCHROMAT REFRACTORS

6" f/9 Apochromat
Only $3995

Meade 6" f/9 Model 152ED Refractor shown with #1697 Computer.

See the Meade ad in this magazine for full specifications and product descriptions. ED = Extremely low dispersion glass which yields color-free virtually perfect images. PPEC = Permanent Periodic Error Correction "Smart Drive."

Model 102 ED 4" f/9 Apochromat and mount	$1795
Model 127 ED 5" f/9 Apochromat and mount	$2295
Model 152 ED 6" f/9 Apochromat and mount	$3995
Model 178 ED 7" f/9 Apochromat and mount	$4995
Photographic field corrector lens (specify telescope model)	$250

DRIVE SYSTEMS

#1664 Electronic Drive with PPEC and 2X, 32X slewing system, dual-axis controller	$295
#1697 Computer Drive, 747 object computer memory, automatic slewing to desired object	$595
8,000 object library of deep-sky targets	add $99
Optional optical encoders for #1697 drive	$299

OPTICAL TUBE ASSEMBLIES (OTA)

Model 102 ED/OTA 4" f/9 OTA only	$1075
Model 127 ED/APO-OTA 5" f/9 OTA only	$1595
Model 152 ED/APO-OTA 6" f/9 OTA only	$2295
Model 178 ED/APO-OTA 7" f/9 OTA only	$2995

EQUATORIAL MOUNTS

LXD 600 mount and standard field tripod	$895
LXD 700 mount and giant field tripod	$1995

NEW MEADE LX100 & LX200 SCHMIDT-CASSEGRAIN TELESCOPES

8" LX200
$1995

NEW MEADE 8" LX200 TELESCOPES

See the Meade ad in this magazine for full specifications and detailed product descriptions.

LX100 Drive, 2X, 32X speed control with PPEC (Permanent Periodic Error Correction "Smart Drive") and dual-axis hand controller.

LX200 Drive, Full electronic control with PPEC, 747 object computer memory and automatic computer controlled slewing to desired object. *NOTE:* A wedge is **not** needed for visual observing with the LX200 Drive. Specify f/6 or f/10 optics at the *same* price.

8" **LX100** Schmidt-Cassegrain with wedge	$1695
8" **LX200** Schmidt-Cassegrain with computer	$1995
Wedge for photographing with LX200	$110
10" **LX100** Schmidt-Cassegrain with super wedge	$2395
10" **LX200** Schmidt-Cassegrain with computer	$2295
Super Wedge for photography with LX200	$395
Optional optical encoders for LX200 models	$289

OTHER SCHMIDT-CASSEGRAINS

Meade 2045D 4" f/10 with motor drive	$695
Meade 2080B 8" f/10 with tripod, wedge, MCOG	$1175
NEW! Model 2120B 10" f/10 with wedge, tripod, MCOG	$1595

PHOTOGRAPHY ACCESSORIES

LUMICON Cassegrain EASY-GUIDER f/6 or f/10	$225
Cassegrain EASY-GUIDER for f/6.3 8" telescope	$195
LUMICON Giant EASY-GUIDER for 10" f/5-f/10 operation	$395
Giant EASY-GUIDER for f/6.3 10" telescope	$295

MEADE STARFINDERS

New 8" f/6 Meade Starfinder telescopes

See the Meade ad in this magazine for full descriptions and technical specifications for 6" to 16" Starfinders. These are complete telescope systems with motor drive, mount, finderscope and 48X eyepiece.

6" f/8 Starfinder 6(add $50 shipping)	$499
8" f/6 Starfinder 8 (add $60 shipping)	$599
10" f/4.5 Starfinder 10 (add $75 shipping)	$699
16" f/4.5 Starfinder 16 (ship. freight COD)	$1995

*All Starfinder telescopes shipped directly from Meade to the purchaser. Please add the indicated shipping charge to the price. LUMICON showroom prices are $96 higher.

ACCESSORIES

LUMICON carries the full line of Meade accessories. See the Meade ad in this magazine for detailed prices and descriptions.

Meade #43 Single axis drive corrector	$99
LUMICON DX200 Dual-axis drive cor.	$249
Meade 47M Dual-axis drive corrector	$399
LUMICON DX2BP Dual-axis drive corrector with built-in battery pack	$299

LUMICON® SKY VECTOR™

Higher Performance — Lower Price

LUMICON ACCESSORIES

LUMICON, 2111 Research Dr., #5, Livermore, CA 94550 (510) 447-9570 FAX (510) 447-9589

SKY VECTOR $399

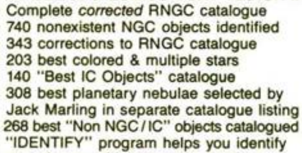
NEW! With over 200 object memory including the 110 Messier objects.

SKY VECTOR II™ $499

Only the LUMICON SKY VECTOR II has size, **true visual magnitude**, and complete **detailed visual description** for **all** 1500 objects in memory.

NGC SKY VECTOR™ $699

IMPROVED!—2002 Additions / Corrections



Improved NGC SKY VECTOR with over 8,500 object memory including complete and corrected RNGC catalogue, and IC and planetary catalogues.

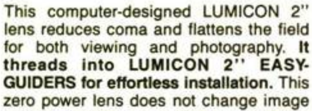
LUMICON NGC SKY VECTOR FEATURES:

- All features of LUMICON SKY VECTOR II
- Complete *corrected* RNGC catalogue
- 740 nonexistent NGC objects identified
- 343 corrections to RNGC catalogue
- 203 best colored & multiple stars
- 140 "Best IC Objects" catalogue
- 308 best planetary nebulae selected by Jack Marling in separate catalogue listing
- 268 best "Non NGC/IC" objects catalogued
- "IDENTIFY" program helps you identify an unknown object seen in eyepiece
- "GUIDE" program leads you to object
- Detailed visual or photographic descriptions
- RS-232 port for computer access
- Includes planets' ephemerides in computer

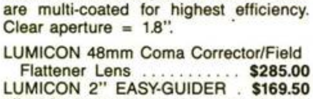
Specify Telescope Type: Meade 2045, 2080, 2120, C-8, C-11, Odyssey 8, 10, 13, 17½, Alt-Azimuth.

Ultima 8, 11 .. **add $25**, C-14 .. **add $75**

COMA CORRECTOR



Coma 1 inch off-axis 17½" f/4.5



Same field with LUMICON coma corrector; smaller, more numerous stars.

This computer-designed LUMICON 2" lens reduces coma and flattens the field for both viewing and photography. **It threads into LUMICON 2" EASY-GUIDERS for effortless installation.** This zero power lens does not change image scale nor shift focus, and all lens surfaces are multi-coated for highest efficiency. Clear aperture = 1.8".

LUMICON 48mm Coma Corrector/Field Flattener Lens	**$285.00**
LUMICON 2" EASY-GUIDER	**$169.50**
2" EASY-GUIDER (Mamiya 645)	**$199.50**
2" Adapter for Pentax 6x7	**$129.00**
2" Adapter for Hasselblad	**$229.00**
2" Adapter for Bronica SQ-A	**$175.00**
2" Extension for viewing	**$26.00**

2" DELUXE BARLOW

1.8x Multiplier Lens (2" Barlow)

LUMICON 1.8x Multiplier Lens (2" Barlow)	**$235.00**

LARGE UV/DUST SEAL

Protect the optics of your 8-14" Schmidt-Cassegrain with a UV/Dust Seal. Simply thread it onto the rear cell, then attach all normal accessories. The large size fits Meade 2120, Celestron-11 and -14 & has a high quality multi coated (removable) 72mm UV filter.

UV/Dust Deal for Celestron C-8	**$39.00**
UV/Dust Seal for Meade 2080, 2045	**$39.00**
UV/Dust Seal (large) for Meade 2120	**$89.50**
UV/Dust Seal for Celestron-11, -14	**$89.50**

NEW! LOW PROFILE HELICAL FOCUSERS

FROM $59.50

LUMICON® LOW PROFILE FOCUSERS

LUMICON now offers 3 different low-profile helical focusers. They stand only 1¼-1½" above the telescope tube. Use the 1¼" or 2" versions for viewing. Use the 2" non-rotating focuser for convenient photography with the LUMICON 2" EASY-GUIDER™.

Select your desired base-plate shape! Flat, 7" OD, 9½" OD, 12½" OD, 16" OD, 21" OD.

LUMICON 1¼" Helical Focuser	**$59.50**
LUMICON 2" Helical Focuser 1½" high	**$65.00**
LUMICON Non-rotating Helical Focuser	**$129.00**
2" rack & pinion focuser, only 2" high	**$139.00**
3 handles for non-rotating focuser	**$12.95**
2"/1¼" adapter w/48mm filter threads	**$20.00**
2" LUMICON EASY-GUIDER	**$169.50**

LUMICON 50mm, 80mm SUPER-FINDER™

Visual Astronomers prefer the LUMICON 80mm SUPER-FINDER™, since hundreds of deep-sky objects, including most Messier objects, are visible directly. SUPER-FINDERS also make nice small portable telescopes. 80mm aperture, F=300mm coated achromat or 50mm, F=200mm coated achromat. Eyepieces and/or star diagonal are extra.

1¼" 50mm Finderscope **$59.50**, right-angle	**$89.50**
1¼" straight-thru 80mm SUPER-FINDER	**$169**
1¼" right-angle 80mm SUPER-FINDER	**$179.50**
1¼" right-angle version, w/star diagonal	**$209**
25mm Cross-hair 1¼" eyepiece (12X)	**$39**
1¼" Star Diagonal **$39**, Mounting Brackets,	**$37**
1¼" Amici Prism diag. for correct left-right views	**$89.50**

LOTS OF ADAPTERS

2" adapter for C-8, Meade 2080, etc.	**$26.00**
2" adapter for C-80, C-100 refractor	**$39.50**
2" adapter for C-70, C-80F, C-100F fluorite	**$39.50**
2" adapter for C-6, Comet Catcher, Meade 312	**$30.00**

EXTENSION TUBES

1" long 1¼" OD thread-in extension	**12.00**
2½" long extension (holds 1¼" filters)	**16.00**
4½" long extension for 1¼" eyepieces	**$25.00**
3" long extension for 2" eyepieces*	**$26.00**
2" long extension for 2" eyepieces*	**$26.00**

VIEWING ADAPTERS

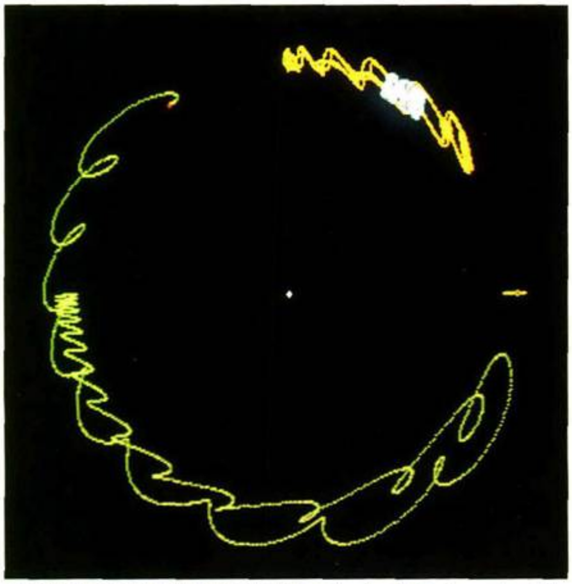
2"/1¼" reducing bushing, threaded 48mm*	**$20.00**
2"/T-thread adapter, threaded 48mm*	**$25.00**
T-thread/1¼" adapter	**$25.00**
F/10 2" or 1¼" eyepiece viewing adapter for Giant Easy-Guider	**$39.50**
Low profile star diagonal eyepiece holder	**$16.00**
Meade 2" Diagonal/Giant Easy-Guider	**$39.50**

**Threaded to hold 48mm filters.*

NEW SOFTWARE ROUNDUP

***Orbits* (1.02)**, *Physics Academic Software, a project of the American Institute of Physics; distributed by the Academic Software Library, P.O. Box 8202, North Carolina State University, Raleigh, NC 27695-8202. Phone (800) 955-8275. $59.95 plus shipping and handling. Multiple-copy license is available. Minimum requirements: IBM PC-compatible computer, 384 KB memory, DOS 2.1, and CGA graphics. Math coprocessor and EGA or VGA display are highly recommended. Available on $5^1/_4$" or $3^1/_2$" diskettes.*

Orbits simulates the gravitational interactions of rockets, planets, and stars under a variety of conditions. The program calculates the positions and velocities of up to five light bodies around one or two massive bodies. You may create your own orbital scenario or study one of nine interactions supplied with the software. Program features include the ability to zoom in and out and to change the force of gravity, and a choice of five reference frames in which to plot the orbital motions.



ORBITS SHOWS THE MOTIONS of Jupiter's Trojan asteroids.

Computing Newsletters

Science Software publishes *Celestial Computing* four times a year. The roughly 40 page newsletter discusses numerical methods, the calculation of orbits, celestial positions, and times of events, and includes book and software reviews. Both printed and electronic ($3^1/_2$" or $5^1/_4$" diskettes) versions of the newsletter are available. The disk version includes QuickBasic™ source code and executable programs pertaining to articles in the newsletter. The cost per year is $29.95 for the printed edition and $19.95 for the disk version ($39.95 and $24.95 respectively for foreign orders). Write to Science Software, 7370 S. Jay Street, Littleton, CO 80123-4661.

A newsletter for CCD enthusiasts comes out four times a year. The 30-page *CCD News* contains information about CCD cameras and image processing, book reviews, product descriptions, and, of course, CCD images. *CCD News* costs $5 a year ($6 in Canada, $10 overseas, and $16 airmail). Make checks payable to K. L. and S. E. Gardner. Write to *CCD News*, 31651 Avon Road, Avon, OH 44011.

***Buil-Thouvenot CCD Atlas of Deep Sky Objects* (1.1)**, *Sky Publishing Corporation, P.O. Box 9111, Belmont, MA 02178. Phone: (617) 864-7360. Complete atlas $129.95; demo $19.95 (you may apply the cost of the demo to the price of the complete atlas). Minimum requirements: IBM PC-compatible, 512 KB memory, DOS 3.2, high-density floppy drive, and VGA graphics. Available on $5^1/_4$" or $3^1/_2$" diskettes. Loading the entire atlas on a hard disk requires at least 27 MB of space.*

French amateurs Christian Buil and Eric Thouvenot have produced this electronic atlas of deep-sky objects. The atlas presents over 3,000 images of galaxies, star clusters, and gaseous nebulae on 656 screens. (The demo disk contains a sample of about 20 screens.) The 16-gray-level, black-and-white images may also be viewed in two false-color modes to enhance image detail. No image-processing capability is provided with the atlas, but you can import and export images with PCX format. Buil and Thouvenot obtained the images with telescopes ranging from an 11-inch Schmidt-Cassegrain to a 40-inch reflector. The images have limiting magnitudes between 18 and 21.

***SeekEasy* (7.01)**, *Correlations Systems, P.O. Box 39, Lomita, CA 90717. Phone (310) 833-3462. $39.95; demo available for $5. Minimum requirements: DOS 2.0, 256 KB memory. Available on $5^1/_4$" or $3^1/_2$" diskettes.*

SeekEasy is a fuzzy-logic text-finding program that provides a way to sort through all those data files you've accumulated for information about one object or a class of objects. It scans your disk files, finding text that even approximately matches the requested text and displays matches in a best-match-shown-first order. The program displays the matched text along with the file name, with the probable match words highlighted. The display includes twelve lines of the text so you can determine its context.

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Until August 31, Future Trends Software will donate one copy of EZCosmos (version 3.0) to the school of your choice with each purchase of EZCosmos. Look inside the software package or ask your dealer for the fulfillment certificate. Upon receipt of the certificate, Future Trends will send a copy of EZCosmos and additional learning materials to the designated school.

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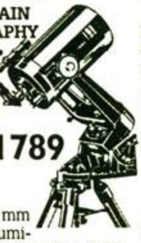

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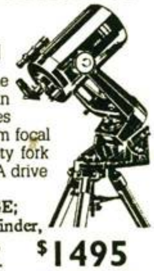

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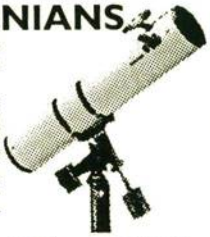

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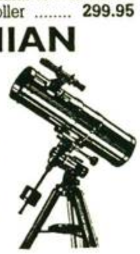

The Meade 4420 is the perfect telescope for the beginner. Its large 4½ inch aperture optical tube & equatorial mounting make it ideal for planetary, deeper space observation or astrophotography. A 1¼ inch rack-and-pinion focuser, 5x24 finderscope and 25mm (36x) eyepiece and full height tripod are included.

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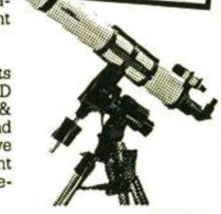

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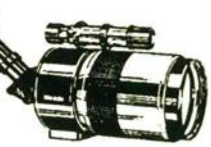

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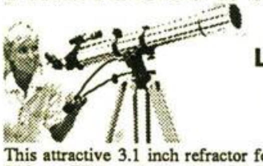

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NEWTONIANS

C4.5 NEWTONIAN

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SCHMIDT- CASSEGRAINS

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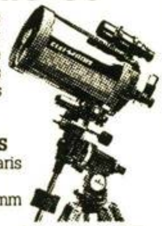

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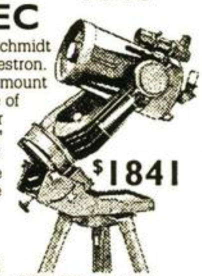

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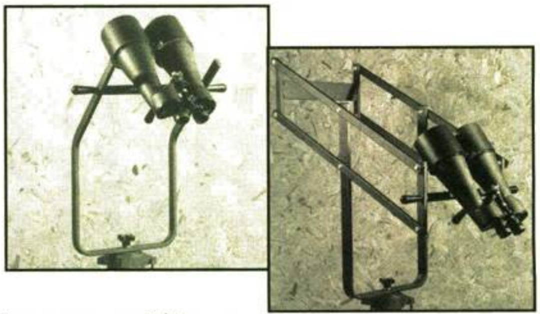
New Astronomy Products

1 Meade's Starfinder Newtonians

The Meade Starfinder 6-inch f/8, 8-inch f/6, and 10-inch f/4.5 reflecting telescopes offer beginning- to intermediate-level amateur astronomers a selection of large-aperture equatorially mounted telescopes (8-inch model shown). Each Starfinder model's optical system is warranted by Meade to resolve to the theoretical limit of its aperture and includes a multi-coated Pyrex®-glass parabolic primary mirror and matching secondary mirror. Optical tube assemblies come with a $1^{1}/_{4}$-inch rack-and-pinion focuser, a 6x30 viewfinder, and a 25mm Modified Achromat eyepiece. The fully machined all-metal mounts use 1-inch-diameter steel polar and declination shafts and are equipped with 115-volt/60Hz motor drive systems for automatic tracking of celestial objects. The mounts also feature setting circles and metal piers and legs.

Meade Instruments Corporation, 1675 Toronto Way, Costa Mesa, CA 92626, (714) 556-2291, FAX: (714) 556-4604. 6-inch: $499.95; 8-inch: $599.95; 10-inch: $699.95. Packing and shipping charges are additional. Send $3 for the new 1992 Meade General Catalog.



2 Binocular Stands from Astronomical Innovations

The MM-50 Mini-Mount (left) can be mounted on any standard camera tripod and can handle binoculars or spotting scopes weighing up to 6 pounds (including 80mm binoculars).

The BM-100 (right) can accommodate binoculars or spotting scopes weighing up to 10 pounds (such as 25x100 binoculars). The swing arms make it possible to adjust the eye height without shifting the pointing position of the binoculars. The mount attaches to Astronomical Innovations' Porta-Pier (PP-10), to any Meade telescope tripod, or to any sturdy tripod that will accept a $^{1}/_{2}$x13 bolt.

Both models include a thrust-bearing kit, large handles, and a heat-treated black wrinkle finish. Both require an accessory "L" bracket (not included) for attaching a binocular to the stand.

Astronomical Innovations, P.O. Box 14853, Lenexa, KS 66285, (913) 894-5775. MM-50: $39.95; BM-100: $119.95.

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Advanced Astro Master™

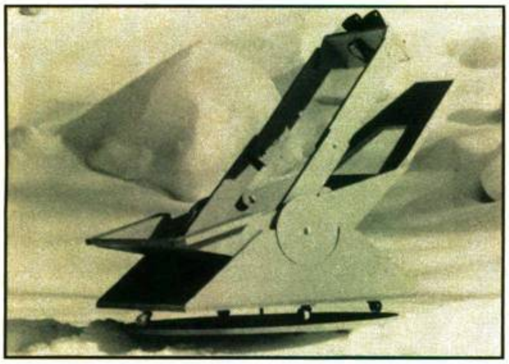
3 New Advanced Astro Master

Celestron's digital setting circles, Advanced Astro Master, provide a real-time readout of right ascension and declination and will guide users to over 8,000 objects in its database. The new version now offers a user-definable catalog of 25 objects. It can be adapted to a wide variety of telescopes, including those with fork-mounts, German equatorial mounts, or Dobsonian mounts. Users can select from three models (each comes with two shaft encoders): the #94145-F with hardware for fork-mounted Celestron 8 and Ultima 11 scopes, the #94145-SP for Celestron Super Polaris mounts, and #94145-N without mounting hardware (suitable for custom installations on homemade Dobsonian mounts).

Celestron International, 2835 Columbia Street, P.O. Box 3578, Torrance, CA 90503, (213) 328-9560. #94145-F: $1,058; #94145-SP: $998; #95145-N: $938.

4 A Binocular Viewing Chair

The StarSeat is a rotating chair made for scanning the heavens through binoculars. With stops for observing in full recline, semi-recline, or upright positions, the chair allows the user to look anywhere in the sky without neck or back strain. The triple-articulated binocular holder can be adjusted to fit people of all sizes. The holder accommodates all types of binoculars, spotting scopes, and rich-field telescopes. The StarSeat comes assembled and painted sky blue and comes with a 30-day money-back guarantee.



Cusick Telescopes, P.O. Box 256, Buena Vista, CO 81211, (719) 395-8253. Introductory price: $299 (regular price $389). UPS shipping at no extra charge. Send $2 for illustrated information on the StarSeat and the Cusick Starhunter-1 double-truss telescope.

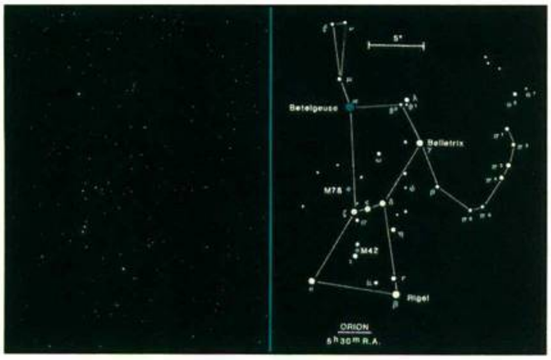
5 New Binoculars from Simmons

Simmons' Premium Series binoculars (right) now includes four models suitable for astronomy applications: a 7x35 Wide-angle, an 8x40 Wide-angle, a 10x50, and a 12x50. The series also includes two zoom models (an 8-17x40 and an 8-20x50) and a compact 8x21 model. Each features fully coated optics, and the 40mm and 50mm models have a quick-focus device.

Roof-prism binoculars with multi-coated optics and a black rubber finish make up the new Gold Medal Series (left). Two models are available: an 8x42 and a 10x42. All Premium and Gold Medal Series binoculars come with a carrying case and neck strap.

Simmons Outdoor Corporation, 14530 S.W. 119th Avenue, Miami, FL 33186, (305) 252-0477, FAX: (305) 252-1913. Premium Series 7x35WA: $99.95; 8x40WA: $104.95; 10x50: $109.95; 12x50: $119.95; 8-17x40: $258.95; 8-20x50: $274.95; 8x21 Compact: $86.95. Gold Medal Series 8x42: $429.95; 10x42: $451.95. Send $2 for a catalog of the complete line of Simmons binoculars.

6 A Constellation Slide Set



Science Graphics, a major supplier of science teaching slides, has introduced its Star Maps slide set, a collection of 40 constellation slides. Each 35mm slide has a photograph of the real star field on the left and a color drawing of the constellation on the right. The drawing labels the bright stars and indicates the positions of bright nebulae, clusters, and galaxies. All first-magnitude stars appear in the proper spectral colors.

Science Graphics, P.O. Box 7516, Bend, OR 97708. Star Maps Slide Set #6600: $60. Write for Science Graphics' catalog of thousands of other astronomy and science slides.

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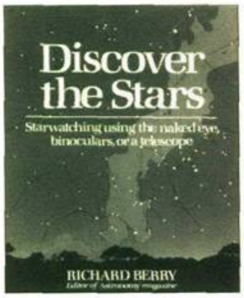

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An introduction to star watching with the naked eye, binoculars or a telescope; contains monthly star maps and 23 charts. By Richard Berry. 7½ x 9¼, 119 pgs., sftbd. #30155 .... **$12.95**

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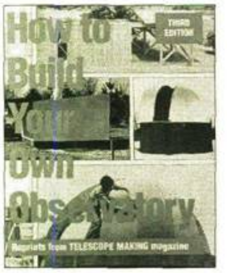

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An anthology describing hundreds of deep-sky objects, including double stars, variable stars, open and globular star clusters, planetary nebulae and galaxies. All of the objects described can be seen using a small backyard telescope. By David J. Eicher, associate editor of **ASTRONOMY**. 6⅜ x 9¼, 336 pgs., 108 b&w photos, approx. 70 illus., sftbd. #30188 .... **$29.95**

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These 102 charts will lead you and your telescope to hundreds of deep-sky objects. 8½ x 11, 112 pgs. #30072 .... **$29.95**

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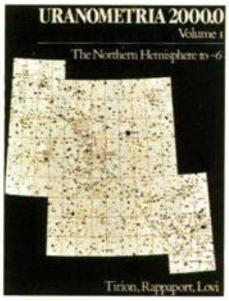

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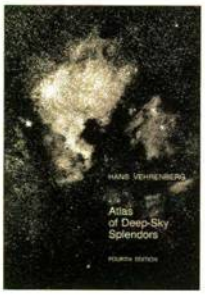

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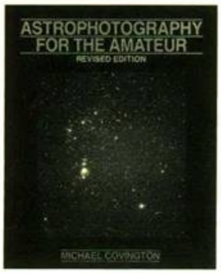

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Meetings & Events

July 1-5
General Assembly of the Royal Astronomical Society of Canada, Calgary, Alberta. Contact: RASC-Calgary Centre, c/o Ms. Dennis Goodman, 28 Southland Crescent SW, Calgary, Alberta, Canada T2W 0K3. Phone: (403) 252-7095.

July 3-5
Rocky Mountain Star Stare, Badger Flats, Colorado. Sponsored by the Colorado Springs Astronomical Society. Contact: Colorado Springs Astronomical Society, P. O. Box 62022, Colorado Springs, CO 80962. Phone: Chris Wetherill at (719) 473-3621.

July 3-5
2nd Annual Gateway to the Universe Star Party, northern Ontario. Sponsored by the North Bay Astronomy Club. Contact: Merlin Clayton, 50 Van Horne Crescent, North Bay, Ontario, Canada P1A 3L3. Phone: (705) 472-1182.

July 13-18
Cosmocon '92 National Convention, San Jose State University, San Jose, California. Sponsored by the Astronomical Association of Northern California. Contact: Don Stone, 4917 Mountain Boulevard, Oakland, CA 94619. Phone: (510) 376-3007.

July 24-25
Table Mountain Star Party, on the summit of Table Mountain near Ellensburg, Washington. Sponsored by the Seattle Astronomical Society. Contact: Tom Barkume, 16031 N. E. 112th Street, Redmond, WA 98052. Phone (206) 881-8118.

July 24-26
Summer Star Party, Sleeping Giant Provincial Park, 40 miles northeast of Thunder Bay, Ontario. Contact: Rob Mace, P. O. Box 146, Vickers Heights, Ontario, Canada P0T 2Z0. Phone: (807) 475-4091.

July 24-26
22nd Annual Summer Seminar, Darling Hill Observatory, Vesper, New York. Sponsored by the Syracuse Astronomical Society. Contact: Sue Rugelis, 601 Bear Street, Syracuse, NY 13208-1101.

July 26-28
Northwoods Starfest, Hobbs Observatory Center, Beaver Creek Reserve, Wisconsin. Sponsored by the Chippewa Falls Astronomical Society. Contact: Bob Elliot, Hobbs Observatory, Route 2, Box 94, Fall Creek, WI 54742. Phone: (715) 877-2787.

July 30 - August 3
6th Annual Alberta Star Party, Kinbrook Island Provincial Park, near Brooks, Alberta. Contact: Calgary Centre - R. A. S. C., P. O. Box 2100, Station M, Calgary, Alberta, Canada T2P 2M5. Phone: Ruth Lewis at (403) 283-0570.

July 31, August 28
Mountain States Star Party, Monte Cristo Campground, Cache/Wasatch National Forest, Utah. Contact: Ogden Astronomical Society, 2336 West 5650 South Street, Roy, UT 84067. Phone: Bob Tillotson at (801) 773-8106.

July 31 - August 1
Summer Spectacular Star Party, Lemon Lake County Park, Crown Point, Indiana. Sponsored by the Calumet Astronomical Society. Phone: (219) 845-9174.

July 31 - August 2
Astronomical League Northwest Regional Convention and High Altitude Star Party, Table Mountain, near Ellensburg, Washington. Contact: Thom Jenkins, Convention Coordinator, P. O. Box 8114, Spokane, WA 99203-0114.

July 31 - August 2
Highland Star Party, Cape Breton Highlands National Park, Nova Scotia. Contact: Cape Breton Astronomical Society, 131 Green Acres Drive, Sydney River, Nova Scotia, Canada B1S 1K5. Phone: John Reppa at (902) 562-2772.

July 31 - August 2
Mountain Astronomers' Rendezvous and Star Party, Battlement Mesa, Colorado. Sponsored by the Denver Astronomical Society. Contact: Denver Astronomical Society, P. O. Box 10814, Denver, CO 80210. Phone: Dave Trott at (303) 871-5172.

July 31 - August 2
Stellafane, Springfield, Vermont. Contact: Stellafane, 60 Victoria Road, Sudbury, MA 01776.

August 7-9
3rd Annual Southern Michigan Universal Regional Festival of Stargazers, near Clare, Michigan. Sponsored by the Genesee Astronomical Society. Contact: Richard Walker, c/o Robert T. Longway Planetarium, East Kearsley Street, Flint, MI 48503. Phone: (313) 627-9524.

August 8
Prairie Astronomy Club Star Party, Hyde Observatory, Holmes Park, Lincoln, Nebraska. Sponsored by the Prairie Astronomy Club. Contact: Lee Thomas, P. O. Box 80553, Lincoln, NE 68501. Phone: (402) 483-5639.

August 15
Annual Star Party, Winchester Canyon Gun Club, Santa Barbara, California. Sponsored by the Santa Barbara Astronomy Club. Contact: Clyde Kirkpatrick, P. O. Box 3702, Santa Barbara, CA 93130. Phone: (805) 966-3695.

August 22
Ohio Turnpike Astronomers Association Convention, Indian Hill Observatory, Chagrin Falls, Ohio. Contact: Chagrin Valley Astronomical Society, P. O. Box 11, Chagrin Falls, OH 44022. Phone: Bob Modic at (216) 636-5789.

August 22
Tidewater Summer Star Party, Tidewater Community College, Portsmouth, Virginia. Contact: Tidewater Community College Astronomical Society, Physics Department, State Route 135, Portsmouth, VA 23703. Phone: Aubrey Hartman at (804) 484-2121 ext. 235.

August 27-30
5th Annual Oregon Star Party and Campout, Ochoco Mountains, Oregon. Sponsored by the Rose City Astronomers. Contact: Check Dethloff, 1511 NW Oakmont Loop, Beaverton, OR 97006. Phone: (503) 629-2145.

August 27-30
2nd Annual Great Plains Star Party, Flint Hills, 75 miles southwest of Kansas City, Kansas. Sponsored by the Kansas Astrophotographers and Observers Society. Contact: Bob Nederman, 9200 Westbrooke Drive, Overland Park, KS 66214. Phone: (800) 473-4382.

August 27-31
Mount Kobau Star Party, near Osoyoos, British Columbia. Contact: Peter Kuzel, 4100 25th Avenue, Vernon, British Columbia, Canada V1T 1P4. Phone: (604) 545-1226. ☐

Please submit announcements at least four months before the date of the meeting or event.

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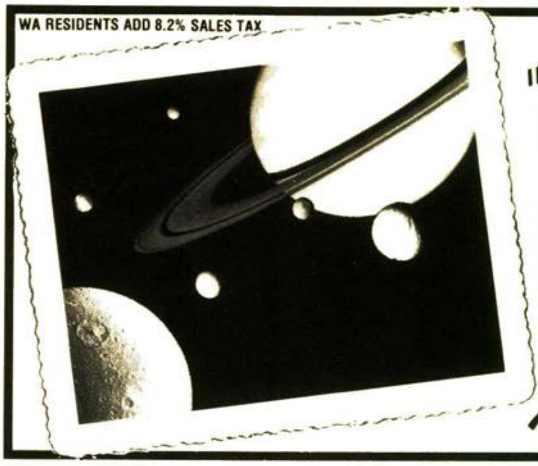

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FOR SALE — New astronomy magazine, *The Trekker: News and Views*. Stars, conventions, story contests, pictures, fan exchange. Bi-monthly. $15 per year. Address: 1231 Garfield Rd., Havertown, PA 19083.

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FOR SALE — *Kimmel's Klingon Recipes.* $8.00. Address: 1231 Garfield Rd., Havertown, PA 19083.

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WANTED — Contact with people living in the Fremantle district of Western Australia who are interested in astronomy. Contact Rachael Vicente, 1 Lygon Court, North Lake, WESTERN AUSTRALIA 6163.

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WANTED — Eighteen- to thirty-inch mirror blank or mirror with diagonal. Contact Northwest Oklahoma Astronomy Club, 1719 Pawnee, Enid, OK 73703. Phone (405) 233-5707.

Readings & Resources

Galactic Archaeology (page 28)

The Supernova Story by Laurence A. Marschall, (Plenum Press, 1988). All about supernovae — including their role in enriching the Galaxy with heavy elements such as oxygen and iron.

"Abundance Ratios as a Function of Metallicity" by J. Craig Wheeler, Christopher Sneden, and James W. Truran, Jr. in *Annual Reviews of Astronomy and Astrophysics,* Volume 27, Pages 279-349 (1989). A technical report on how astronomers use different chemical elements to track the Galaxy's evolution.

Desperately Seeking Jupiters (page 36)

"Do Brown Dwarfs Really Exist?" by Deborah Byrd, ASTRONOMY, April 1989. Describes how brown dwarfs may form and astronomers' searches for these elusive objects.

"Lost and Found: Pulsar Planets" by David Bruning, ASTRONOMY, June 1992. The story of Wolszczan and Frail's discovery of the first planets detected outside of our solar system and the retraction by Andrew Lyne of his group's discovery of another pulsar planet.

Ulysses Meets a Giant (page 42)

"Seeing the Unseen Sun" by Richard Talcott, ASTRONOMY, January 1990. A summary of the Ulysses mission.

How to Improve Your Image (page 60)

"Finding the Best Observing Site" by Tim Hunter, ASTRONOMY, December 1989. How to rate your observing site choices for the best skies and seeing conditions.

Going Digital with Color (page 80)

"Celestial Seeing: Three Imaging Technologies" by Richard Berry, ASTRONOMY, February 1992. A 6-page comparison of film, video, and CCD techniques.

Astronomical Image Processing by Richard Berry, Willmann-Bell, Inc. An image-processing software and guidebook combination.

"CCD News," a quarterly newsletter for CCD imaging fans. Available for $5 per year in the United States. ($6 US in Canada, $16 US overseas for airmail). Write to: CCD News, 31651 Avon Road, Avon, OH 44011.

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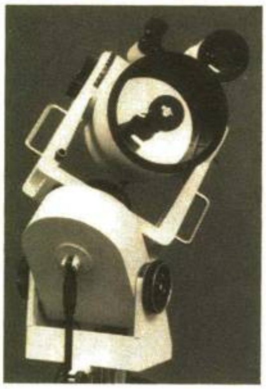

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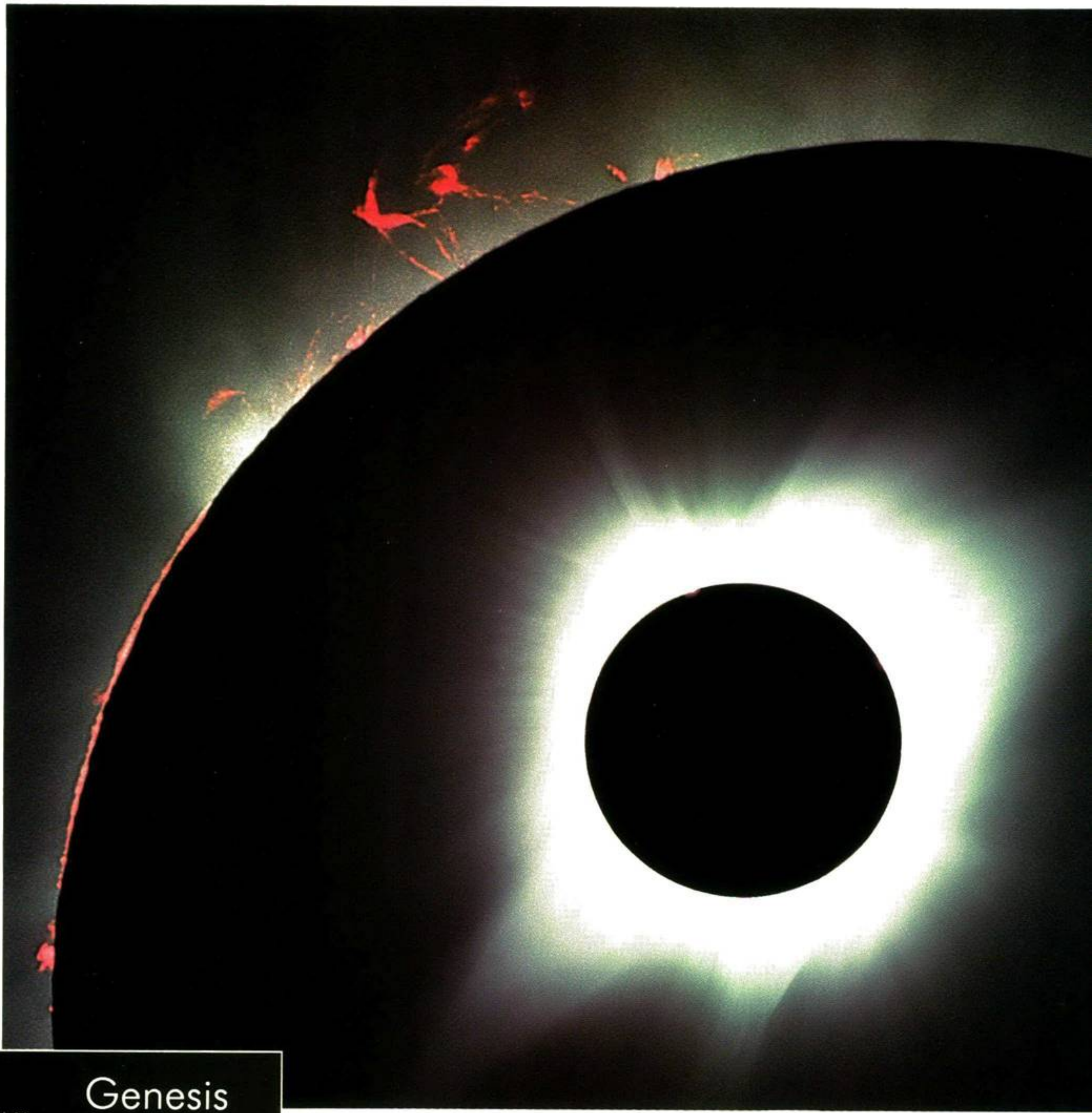
ASTRONOMY
July 1992

Adorama 110, 111
Andromeda Software 104
ARC Software 19
Astronomics 21, 23
Bethany Sciences 94
BLUE SKY Pages 92, 93
Brazen Sky Productions 12
California Telescope Co. 86
Carlino Woodcraft 101
CEB Metasystems 21
Celestron International 64, 65, 116
City Camera 101
Coulter Optical Inc. 13
Edmund Scientific Company 12
FC Meichsner Co. 105
Focus Camera 102, 103
Fremont, Jim 104
Fujinon 114
Future Trends Software 25
Galleria Optics 94
Haag, Robert A. - Meteorites 16
Images 109
International Dark-Sky Assoc. 101
Jim's Mobile (JMI, Inc.) 17
Kalmbach - *Astronomy* 109
Kalmbach - *Binders* 101
Kalmbach - *Books* 101
Kalmbach - *Observing The Moon* 91
Kalmbach - *Sky Mart* 106, 107
Khan Scope Centre 93
Los Angeles Optical 23
Lumicon 98, 99
Meade Instruments 2, 3, 8, 9, 10, 11
Newbridge Communications 26, 27
Newport Glass Works 12
Newport Industrial Glass, Inc. 104
Orion Telescope Center 14, 15
P & S Skyproducts 104
Parks Optical 74
Prochaska Science 94
READER's Exchange 110, 112
Reid, Jim (Bed & Breakfast) 16
Scope City 97
Seeside Engineering 12
Shutan Camera & Video 96
Star Hill Inn 16
Starry Messenger, The 105
Technical Innovations 94
Tele Vue Optics, Inc. 7, 115
Thousand Oaks Optical 86
Tuthill, Roger W. Inc. 23
University Optics Inc. 113
Vista Instruments 16
Vogel Enterprises, Inc. 105
Wholesale Optics (Pauli's) 79
Wholesale Optics of Penn 97, 109
Willman-Bell 108
Zephyr Services 95



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